New Scientist

WEEKLY 29 November 2025

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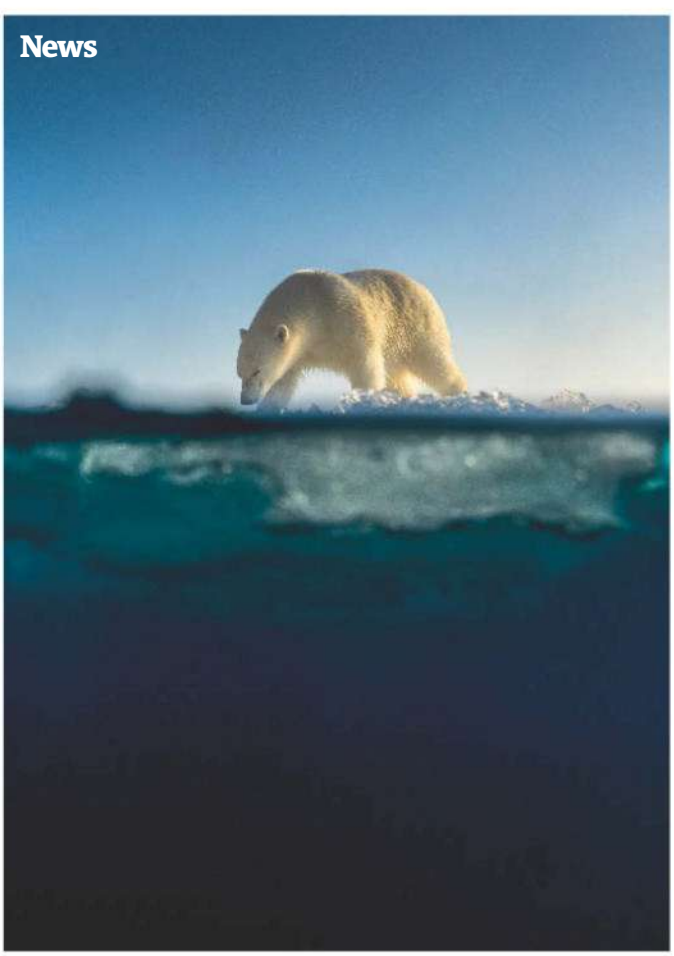

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A complete cop out

The annual UN climate summits are no longer fit for purpose

IMAGINE you have a life-threatening disease. All available scientific tests point to a clear diagnosis, and a deadly prognosis. But when you visit your doctor, they make no direct mention of the disease. After some brief pleasantries, they shake you by the hand and ask you to book another appointment in 12 months' time.

None of us would consider this to be an acceptable standard of healthcare, and yet this is the approach we are taking towards Earth's climate. The United Nations's Conference of the Parties (COP) summits, the 30th of which concluded in Belém, Brazil, late last week, have inarguably delivered important progress in tackling climate change, most notably the 2015 Paris Agreement to limit warming to below 1.5°C. Although that goal has all but failed, we are certainly on course for far less warming than we would be without it.

But it is also clear that the COP process is no longer fit for purpose. As we report on page 6, COP30 ended without even a mention of fossil fuels, the leading cause of climate change, in its final agreement.

"Countries in favour of climate action should throw their might behind solar and batteries"

Despite more than 80 nations calling for a road map to "transition away from fossil fuels" – a phrase that appeared in the COP28 agreement signed in Dubai in 2023 – petrostates, including former COP host Saudia Arabia, worked to block any such agreement. Because COP requires consensus, we are left with nothing but the promise of more talks to be held at COP31 in Turkey next year.

This state of affairs cannot be allowed to continue, but reforming the COP process will be no easy task. Instead, if the argument for bringing an end to the fossil fuel era cannot be made through science or politics, then we must turn to technology and economics.

Countries in favour of climate action should throw their might behind solar power and batteries, flooding the world with cheap energy that will beat out oil and gas. Nations that want a liveable future could impose economic sanctions on those who appear not to care. Whatever we do, a simple "see you next year" is no longer an acceptable option. ▮

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Entomology

Grasshopper looks pretty in pink

Captured here enjoying the sun is an incredibly rare pink female robust grasshopper (*Sigaus robustus*). These insects are usually grey or brown, which acts as camouflage among the stones of their native habitat on the edge of New Zealand's Mackenzie basin. But some of them are pink, which is thought to be the result of a genetic mutation that causes overproduction of red pigment.

SAMANTHA TURNER/NEW ZEALAND DOC

Climate change

COP30 staggers to the finish line

The 194 states taking part in UN climate negotiations reaffirmed the Paris Agreement following the US withdrawal, even if they agreed on little else, finds **Alec Luhn**

THE United Nations COP30 climate summit in Brazil was flooded by torrential rainfall, stormed by protesters and partially burned down by an electrical fire. The final session was briefly suspended due to countries' objections that the texts they had agreed were too weak.

Nevertheless, the only truly global process for climate action staggered on, with every nation except the United States having spent 12 days in the Amazon negotiating a shared lodestar.

The final decision didn't mention fossil fuels, the cause of nearly three-quarters of greenhouse gas emissions, even though the agreement made at COP28 in Dubai called for a transition away from these energy sources. More than 80 countries at COP30 sought a road map to achieve this fossil fuel transition. But oil-producing countries removed it from the texts, which must be agreed unanimously by all 194 states.

Rules of the game

"A consensus imposed under climate denialism is a failed agreement," Colombia delegate Diana Mejia told the room, arguing, along with the delegates from Panama and Uruguay, that Brazil had ignored their requests to speak before it gavelled through the final texts.

In the end, Brazil, which claimed not to have seen the requests, promised them it would help develop a fossil-fuel transition road map outside the UN.

"It's like making a board game," Natalie Jones at the International Institute for Sustainable Development says of the failed road map. "We're playing the game, but some people are still arguing about what the rules should be."

Yet the final decision – called the "global mutirão" after an Indigenous Brazilian word for "collective efforts" – did at least demonstrate that international cooperation on climate has survived what have been "some heavy blows this year", as UN climate secretary Simon Stiell said in his closing speech.

Donald Trump again pulled the US, the world's second-largest emitter, out of the COP process, and Argentina threatened to leave as well, raising fears the annual negotiations would fracture. At other global meetings this year, Washington torpedoed talks to limit shipping emissions and plastic pollution.

Companies, industry groups and philanthropic foundations have also rowed back on climate commitments, with Bill Gates calling for COP30 to focus on poverty and disease rather than emissions.

Ten years after the Paris Agreement at COP21, which set out a limit of 2°C of warming compared with the pre-industrial average, and an aspiration to limit warming to 1.5°C, we are only on track for 2.6°C. Last year, top scientists and diplomats wrote to the UN that the COP process "is no longer fit for purpose". But former Ireland president Mary Robinson, one of the letter's authors, said in a statement after COP30 that most countries are moving forward "at a time when multilateralism is being tested".

Nations stressed in the main text that they remained united behind the Paris Agreement and the findings of the Intergovernmental Panel on Climate Change. Taken together with the climate pledges in a declaration by the G20 summit of large economies the same day, which the US also boycotted, it is a "really powerful pushback and rebuke to Trump", according to Joanna Depledge, a COP historian at the University of Cambridge.

It also sends a strong signal to businesses, investors and subnational governments, she says.

As foreign aid budgets shrink – the US has shuttered its aid agency entirely – lower-income countries have complained that big historical emitters aren't supporting them in adapting to climate threats. COP30 agreed to develop a "just transition mechanism" to help this. It also pledged to triple adaptation finance, but it remains unclear how much money that should be, and the initial deadline of 2030 has been delayed to 2035.

"Apart from the just transition mechanism... I don't have anything to celebrate," says Harjeet Singh at the Satat Sampada Climate Foundation, which advocates for people who are vulnerable to the impacts of climate change. "We should have done much better."

PABLO PORCIUNCULA/AFP VIA GETTY IMAGES

Protesters at COP30 have been calling for an end to fossil fuels

2°C
Global warming limit above pre-industrial levels set in the Paris Agreement at COP21

2.6°C
How much global temperatures are now expected to rise above pre-industrial levels

Why is climate action stalling as Earth gets hotter?

You might expect countries to step up their climate initiatives, but we're actually seeing the opposite, says **Michael Le Page**

Although COP30 took place in Belém on the edge of the Amazon, it failed to agree a road map to halt and reverse deforestation, despite it being pushed by more than 90 countries. Before the summit, Brazil launched the Tropical Forests Forever Facility, an investment fund that pays returns to countries for each hectare of forest they leave standing.

Brazil and donor countries have committed $6.6 billion, far less than the $25 billion goal. The rules under which the fund will operate need to be tightened, says Kate Dooley at the University of Melbourne, but "it's a welcome step away from carbon offsetting that fails to protect the climate at all".

"Brazil itself taking a bit of leadership on deforestation is one of the best outcomes we could hope for COP30," says Marco Duso, a sustainability consultant at Ernst and Young. "And it's taking that leadership also internationally." ▮

TEN years on from the Paris Agreement, we should be seeing a massive ratcheting up of climate action. Instead, the past four years have seen almost no progress – including at the latest COP summit (see left), which failed to take meaningful steps towards phasing out fossil fuels or ending deforestation. What's going on?

I don't know. But I'm starting to fear that, rather than responding more rationally as the world heats up and the impacts get ever more serious, our responses are becoming more irrational. If that is the case, climate impacts are going to be much worse than they would otherwise be.

Let's start by going back to the Paris Agreement of 2015. The whole idea of an international climate agreement under which every country sets its own targets for limiting greenhouse emissions seemed ludicrous to me. As did the idea of an "aspirational" target of restricting global temperature increase to 1.5°C, which was wildly disconnected from what countries were planning to do. Supporters claimed it would be solved by a "ratchet mechanism", under which countries would progressively increase their targets.

Greenwashing exercise

I came away from Paris regarding it as a gigantic greenwashing exercise. My expectation was that it would have little immediate impact, but as the effects of warming became more obvious, action would start to ramp up. In other words, reason would prevail.

So far, the opposite has happened. In the lead-up to Paris, in October 2015, the Climate Action Tracker project estimated that the world was heading for warming of around 3.6°C by 2100, based on current policies and action. By 2021, that estimate had been revised down to around 2.6°C. That's a massive improvement – it seemed Paris was working.

But the latest Climate Action Tracker report ahead of the COP30 summit makes for grim reading. For the fourth year in a row there has been "little to no measurable progress". "Global progress is stalling," the report says. "While a handful of countries are making genuine progress, their efforts are counterbalanced by others delaying, or rolling back climate policies."

> "No, we aren't doomed. But the longer it takes for reason to prevail, the worse the outcome will be"

Yes, renewable energy generation is growing much faster than predicted. But this is being offset by the huge sums being poured into fossil fuels.

The problem isn't just the failure to slash emissions. We are still building cities on sinking land next to rising seas.

The big question is why climate action is stalling instead of ramping up further. In some countries, it is obviously due to the election of politicians who don't see climate change as a priority or unashamedly deny it, as reflected by the US withdrawing from the Paris Agreement.

Even governments that say climate is a priority are doing less, however, seemingly on the basis that there are more urgent issues to deal with, such as the cost of living crisis. Yet the cost of living crisis is, in part, a climate crisis, with extreme weather helping drive up food prices. As warming continues, the impact on food and the wider economy is only going to become more serious.

Are we going to get to the point where governments say they can't act on climate change because of the costs of dealing with major cities being inundated by rising seas? Are people's fears about the state of the world going to make them keep voting for climate deniers despite pollsters telling us that most people worldwide want more climate action?

After year after year of record-smashing heat, it has never been more obvious that climate change is real and really bad. But perhaps that's the problem. The philosopher Martha Nussbaum has argued that fear is a tremendously negative force that makes people abandon rationality and focus on their immediate welfare rather than the long-term good. And there is some evidence that environmental stresses make people behave irrationally.

People tend to leap straight from "things are bad" to "we're all doomed". No, we aren't doomed. But the longer it takes for reason to prevail, the worse the outcome will be. Maybe what we're seeing is just a blip related to the pandemic and Russia's war on Ukraine – or maybe there's something more worrying happening. ▮

Michael Le Page is an environment reporter at *New Scientist*

Health

Bacteria linked to common form of IBD

Ulcerative colitis is one of the two main kinds of inflammatory bowel disease, and we may now have a better idea of its causes and how to treat it, finds **Michael Le Page**

A TOXIN produced by bacteria found in dirty water kills off immune cells in the lining of the colon, meaning people whose guts are colonised by these bacteria are much more likely to develop a condition known as ulcerative colitis.

That is the conclusion of a series of studies in people and animals conducted by Xuena Zhang at Nanjing University in China and her colleagues. If this finding is confirmed, it could lead to new treatments for the condition.

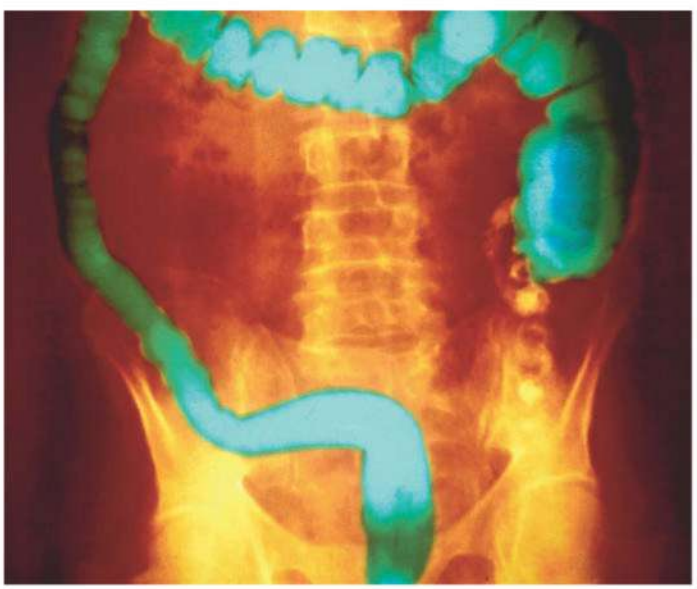
Ulcerative colitis is one of the two main kinds of inflammatory bowel disease, or IBD. It is characterised by inflammation of the lining of the colon and rectum. People typically have periods of no symptoms that alternate with flare-ups. The most serious cases can require the removal of the colon.

The causes of ulcerative colitis have been uncertain, but it is usually regarded as an autoimmune disease with complex environmental and genetic causes. Zhang and her team suspected that immune cells known as macrophages might play a role.

"The case is strong for this toxin disrupting gut immunity by depleting immune cells"

Macrophages are found in most tissues in the body, where they mop up any debris or bacteria and also help regulate local immune responses. They can sound the alarm to call in more immune cells, causing inflammation, but – crucially – they can also sound the all-clear, reducing inflammation.

In colon tissue taken from people with ulcerative colitis, the researchers found lower levels of resident macrophage cells than in people without the condition. They then showed that killing macrophages in the colons of mice made them more susceptible to ulcerative colitis. The researchers think the loss of the protection usually provided by the macrophages results in the lining of the colon becoming damaged and inflamed.



BSIP SA/ALAMY

Ulcerative colitis causes inflammation in the lining of the colon

But why were macrophage levels lower in people with ulcerative colitis? By testing samples of faecal bacteria from people with the condition, the team found a toxin called aerolysin, which turns out to be highly damaging to macrophages but has little effect on other cells in the gut.

Aerolysin is produced by some strains of bacteria in the genus *Aeromonas*, which are commonly found in fresh and brackish waters. The researchers call the strains that produce aerolysin MTB (macrophage-toxic bacteria).

When the team deliberately infected mice with MTB, this made them more susceptible to ulcerative colitis. But if the gene for aerolysin was deleted from the bacteria, or if the toxin was neutralised by antibodies, the mice didn't become more susceptible.

Finally, the researchers looked for *Aeromonas* bacteria in stool samples. They found them in 72 per cent of 79 people with ulcerative colitis, but only 12 per cent of 480 people without the condition (*Science*, doi.org/qfh8). This test couldn't reveal whether these bacteria were MTB and therefore if they produced aerolysin.

Overall, the studies point to a complex picture. Not every case of ulcerative colitis may involve MTB, and people can also have MTB in their guts without developing the condition.

"We cannot conclude that MTB is the sole cause of ulcerative colitis," says Zhang. "Persistent MTB infection can induce a hypersensitive state in the colon, but this does not mean that every infected individual will develop colitis. The occurrence of colitis in this context is undoubtedly influenced by environmental and genetic factors," she says.

DENNIS KUNKEL/SPL

Aeromonas bacteria could make people more susceptible to ulcerative colitis

There are at least three potential approaches for developing new treatments, says Zhang. One would be to develop drugs that neutralise the toxin. Another would be to develop vaccines targeting either the toxin or the bacteria that produce it. The third would be to use viruses that kill specific bacteria, known as phage therapy, to eliminate the toxin-producing bacteria.

"The case is strong for the MTB toxin disrupting gut immunity by depleting special macrophages in the gut tissue," says Martin Kriegel at University Hospital Münster in Germany.

He points out that when the team killed off all gut bacteria in mice, then infected them with MTB, the animals didn't become more susceptible to ulcerative colitis. This suggests other, as-yet-unidentified bacteria also play a role.

"Nevertheless, it may represent an important, missing factor in the multi-step pathogenesis of ulcerative colitis, at least in China," says Kriegel.

Zhang and her team now plan to do wider epidemiological studies to try to confirm the link between MTB and ulcerative colitis. If MTB infections do play a role and are becoming more common, it might help explain why the incidence of IBD is rising. ▮

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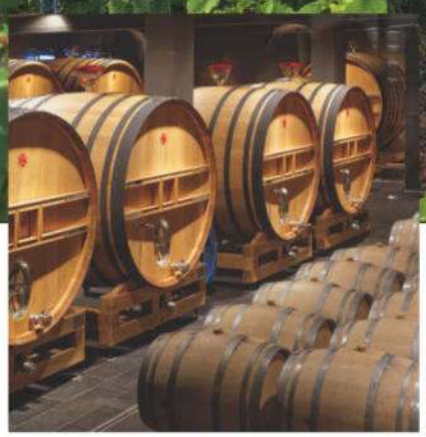

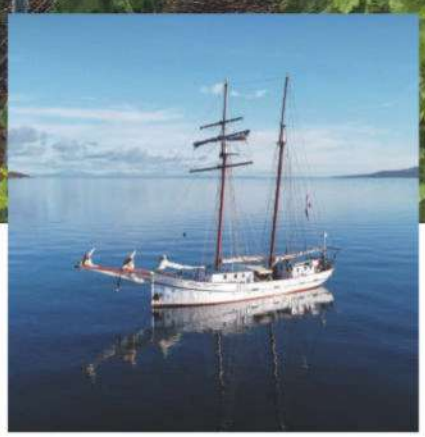

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Evolution

Sperm's beginnings go all the way back to before multicellular animals

James Woodford

THE evolutionary origin of sperm can be traced back to a single-celled ancestor of all living animals.

Almost all animals reproduce by having a single-celled stage of their life cycle, involving two types of sex cells, or gametes. Eggs are larger cells containing genetic material and the resources for early development, whereas sperm transport genetic material out of one body, locate an egg and fuse with it to create a fertilised zygote.

"Sperm carries the machinery that allows life to pass from one generation to the next," says Arthur Matte at the University of Cambridge. "It retains traces of more than 700 million years of evolution and is likely tied to the origin of animals themselves. We wanted to retrace that long evolutionary story to understand where sperm came from."

Matte and his colleagues used open-science datasets containing information about the proteins that make up sperm in 32 animal species, including humans. They then combined that data with the genomes of 62 organisms, including some single-celled groups related to animals, to trace the diversification of sperm across animal lineages.

"Sperm isn't a flashy new invention of multicellular life; it is built on a unicellular body plan"

They found that a "sperm toolkit" consisting of around 300 gene families made up the core genome of the last universal common sperm (bioRxiv, doi.org/qfst).

"We could see that a lot of the sperm machinery had major innovations even before multicellular animals existed, long before sperm themselves," says Matte.

This suggests that the sperm machinery, "a flagellum pushing around a single cell", had already evolved before multicellular animal life emerged, he says.

It implies that our distant ancestors were once all single cells moving about in the ocean and the sperm toolkit first took shape in a swimming unicellular ancestor, long before animals existed.

"As animals developed multicellularity and cell specialisation, they did not invent sperm from scratch; they re-used the body plan of these swimming ancestors as a foundation for sperm," says Matte. "In other words, sperm isn't a flashy new invention of multicellular life; it is built on a unicellular body plan repurposed for reproduction."

The study also revealed that the innovations that led to the immense diversity of modern sperm mostly altered the cell's head, while the tail has changed little since the common ancestor.

There are many different modes of fertilisation, with some sperm meeting eggs inside a body and others swimming in the open ocean, says team member Adria LeBoeuf, also at the University of Cambridge. "Finding an egg in these different environments will be different and require different machinery," she says. "But wherever you are, you'll still need to swim, so the tail is quite conserved."

"It's a lovely example of how evolution works to reshape what's there rather than inventing mechanisms from scratch," says Jenny Graves at La Trobe University in Melbourne, Australia. ▮

Palaeontology

Ancient tracks might be record of a sea turtle stampede

STRANGE impressions in a rock face in Italy may have been left by sea turtles attempting to escape an earthquake around 83 million years ago.

Free climbers discovered the unusual features in an area that is off limits to the public on the slopes of Monte Cònero on Italy's east coast.

There are more than 1000 prints in two locations – one more than 100 metres above the ocean, and a second shelf that has fallen to La Vela beach. These rocks consist of limestone that formed from fine sediment on a shallow seabed in the Cretaceous Period.

The climbers took photos that were later shown to Alessandro Montanari at the Geological Observatory of Coldigioco in Italy and his colleagues. The scientists then gained permission from the managers of the Cònero Regional Park to survey the area.

PAOLO SANDRONI

The possible turtle tracks were found on the slopes of Monte Cònero in Italy

Montanari says only two groups of vertebrates inhabited the oceans at the time: fish and marine reptiles. The team ruled out fish, plesiosaurs and mosasaurs, leaving sea turtles as the most likely candidates (*Cretaceous Research*, doi.org/qfj7).

Because the seafloor is such a dynamic and soft environment, for the prints to be preserved, they would have had to be buried almost instantly after they were made – which could have happened during an earthquake.

"[It may have been] a strong earthquake, which scared the bejesus out of these poor animals who were peacefully hanging around the nutrient-rich, shallow water environment," says Montanari.

"They all swim in panic towards the open sea on the west of the reef, and some of them reached the oozy seafloor, leaving their paddle prints."

However, this is just a hypothesis and the team now hopes to involve specialist ichnologists, who study trace fossils such as trackways, for the next stage of research. ▮ JW

Health

Loss of Y affects lung cancer outcomes

Tumour cells without Y chromosomes may have mixed effects on the condition's progression

Liam Drew

MEN with the most common form of lung cancer seem to be uniquely susceptible to losing the Y chromosome from their cells, which could help the cancer proliferate – but may also boost the efficacy of a common treatment.

As men age, many of their cells are prone to mutating and losing their Y chromosomes. With immune cells, this has been linked to heart disease and a shorter lifespan. Evidence is also accumulating that cancerous cells shedding their Y chromosomes affects the condition's progression.

For a cell, loss of Y is a binary event: it either happens or it doesn't. But what seems to be important for health outcomes is the fraction of cells of a particular type that lack a Y chromosome.

The latest research began with Dawn DeMeo at Brigham and Women's Hospital in Boston, Massachusetts, and her colleagues analysing the expression levels of Y chromosome genes in a public database of samples of lung adenocarcinoma, the most common type of lung cancer, which starts in the mucus-making cells lining the airways.

They found that the cancerous cells frequently lacked Y chromosomes, unlike healthy lung cells and immune cells (bioRxiv, doi.org/g6hwbq). This occurred regardless of whether or not the tissue donors smoked, a behaviour known to cause lung cancer and induce loss of Y.

The loss of Y also accumulated. "There is a group of people who lose more and more Y chromosomes in more and more cells, so a greater proportion of the tumour exhibits loss of Y," says team member John Quackenbush at Harvard University.

To uncover why this occurs, the team examined other genetic changes in cells without Y. This linked the loss to the reduced expression of a common set of antigens that cancer cells often make, which ordinarily signal to immune system cells called T-cells that these cancer cells are abnormal and should be attacked. This reduced expression then enables the Y-less cancer cells to proliferate unchecked.

"As the tumour cells lose Y chromosomes, they are increasingly able to evade immune surveillance"

"What that suggests is that as the tumour cells lose their Y chromosomes, they're increasingly able to evade immune surveillance, and that would argue that they're selected for," says Quackenbush. T-cells were consistently less common in samples characterised by loss of Y than in Y-retaining tumours.

More positive news came when the researchers looked at data from 832 people with lung adenocarcinoma who had been treated with pembrolizumab, an immune checkpoint inhibitor that reinvigorates a person's natural immune response to tumours by reversing T-cell suppression. They saw that loss of Y was associated with better treatment outcomes.

"When you have LOY [loss of Y], you're more responsive to checkpoint inhibitors," says Dan Theodorescu at the University of Arizona, who uncovered the same outcome in bladder cancer in 2023.

Research needs to uncover how the actions of such mutations and their survival effects vary between cancer types, says Theodorescu. ▮

Space

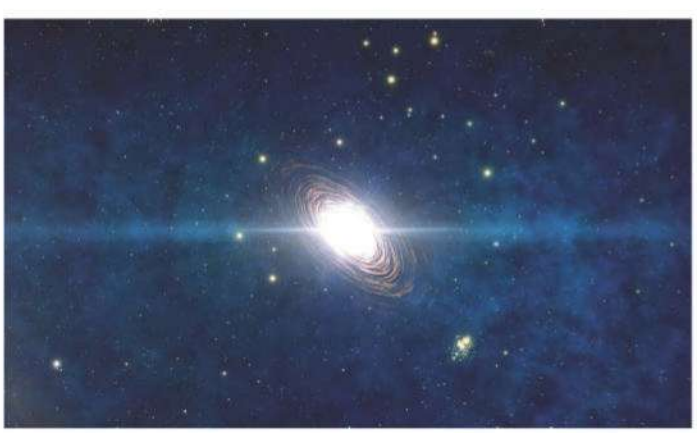
We may have found proof of the biggest stars ever seen

THE James Webb Space Telescope (JWST) is allowing us to examine distant galaxies in the far reaches of the early universe for the first time. Some of these have chemical signatures that seem to point to exotic supermassive stars with masses up to 10,000 times that of the sun.

"All of our evolution models of the galaxies... rely on the fact that stars cannot be more massive than 120 solar masses or so," says Devesh Nandal at the Harvard-Smithsonian Center for Astrophysics in Massachusetts. "There, of course, have been theoretical ideas that explore stars... more massive than that, but never has there ever been a real observation that one can point to."

That is, until now. Nandal and his colleagues examined JWST observations of a distant galaxy called GS 3073 and found unusually high amounts of nitrogen in its chemical signatures (*The Astrophysical Journal Letters*, doi.org/qfkn).

There is a type of hypothesised primordial star, called a Population III star, that models indicate could grow extremely large and form much more nitrogen than regular stars. Nandal and his team calculated that just a few Population III stars with masses between 1000 and 10,000 times that of the sun could account for the excess nitrogen in GS 3073. "Our work shows the strongest evidence to date of Population III supermassive stars in the early universe," he says.



NOIRLAB/NSF/AURA/J. DA SILVA/M. ZAMANI/SPACEENGINE

An artist's impression of a Population III star 300 times more massive than our sun

However, some disagree. "Population III must be associated with a near-pristine environment" without many elements heavier than helium, says Roberto Maiolino at the University of Cambridge. "On the contrary, GS 3073 is chemically a fairly mature galaxy. So it does not seem to match the kind of environment where you expect to find Population III." ▮

Leah Crane

Climate change

Storm-like vortices of water threaten Antarctic ice shelves

Alec Luhn

UNDERWATER "storms" are melting the ice shelf protecting the Thwaites glacier in Antarctica, raising concerns that we are underestimating future sea level rise.

Up to 10 kilometres wide, these storm-like vortices start swirling when waters of different density or temperature collide in the open ocean. Some of them barrel towards the coast, which in Antarctica is largely made up of ice shelves – the floating extensions of glaciers that stick dozens of kilometres out into the sea.

"They have so much motion and they're really hard to stop," says Mattia Poinelli at the University of California, Irvine. "So the only way they could go is just get trapped under the ice."

Poinelli and his team's modelling showed that these storms were responsible for one-fifth of the total melt of the Thwaites and neighbouring Pine Island ice over nine months (*Nature Geosciences*, doi.org/qfsq). It is the first study to quantify the impact of these storms across an entire ice shelf.

The Thwaites glacier loses 50 billion tonnes of ice each year and could raise sea levels 65 centimetres if it collapsed.

In the waters around Antarctica, several hundred metres of colder, fresher water sit on top of warmer, saltier deep water. If a storm becomes trapped in the cavity under an ice shelf, its whirling pushes the cold surface water outwards away from the centre of the vortex, drawing warm deep water up into the resulting void and melting the ice shelf from the bottom up.

As the climate warms and more fresh meltwater pours off Antarctica, underwater storms are likely to intensify, which could cause more sea level rise than we expect. ▮

For more on polar warming, turn to page 19

Animal behaviour

Mouse 'midwives' help mothers give birth

Grace Wade

VIOLET J. IVAN/NYU GROSSMAN SCHOOL OF MEDICINE

Mice helped remove the pups from the mother and keep them clean

MICE seem to assist pregnant females when they have trouble giving birth. This is thought to be the first official sighting of such assistance in non-primates.

Humans are the only animal known to aid one another consistently during birth. Other primates, such as black snub-nosed monkeys and bonobos, have also been seen helping one another, but only occasionally.

Now, the same behaviour has been observed in mice. Robert Froemke at NYU Langone Health in New York City and his colleagues were recording the brain activity of mice giving birth as part of a separate study. They found other mice in the same cage sometimes seemed to be assisting with pup delivery.

To learn more, they genetically engineered pregnant mice to lack oxytocin receptors. Oxytocin induces uterine contractions, which help push the mouse pups out of the birth canal. Without these contractions, they are likely to get stuck and die. The mother often won't survive either.

The researchers housed 10 of these mice in individual cages, pairing each one with a female mouse that had previously given birth to at least one litter. A separate group of seven pregnant mice without oxytocin receptors were kept in individual cages by themselves.

During labour, the mouse mothers assisted the pregnant mice when their pups became stuck. "She will come over and act like a little mouse midwife and very carefully, with her mouth and with her paws, pull the pup out," says Froemke, who presented the findings at a meeting of the Society for Neuroscience in San Diego, California. The assisting mice also broke open the fluid-filled sac encasing the newborns, allowing them to breathe.

> **"The mouse will come over and, very carefully, with her mouth and paws, pull the pup out"**

Nine of the 10 pregnant mice paired with these mouse "midwives" survived labour, and about 90 per cent of their litters did too, on average. Only one of the solitary pregnant mice survived giving birth, and all of the pups in this group died.

To assess whether the presence of a mouse that had previously given birth was required, the team placed another 14 pregnant mice without oxytocin receptors in separate cages. Seven of them were paired with male mice, four with female mice that had never given birth and three with female mice that hadn't all given birth but did also lack oxytocin receptors. These receptors are also thought to be important for social interactions.

Nearly 60 per cent of pregnant mice housed with male mice and half of those housed with non-mother females survived labour. But these animals didn't pull the pups out during delivery. Instead, the males mounted the pregnant female, which placed pressure on her back, helping to push the pups out. Meanwhile, the non-mother females groomed pregnant females and similarly applied abdominal pressure. Among the three mice kept with females that lacked oxytocin receptors, one survived.

None of the pups in this part of the experiment survived, however, as their fluid-filled sacs were left intact. "It seems that the experience of being a mother is required to be a successful [mouse] midwife," says Froemke.

"Parental care is one of the most influential social interactions," says Bianca Jones Marlin at Columbia University in New York. These results emphasise that it "requires support", she says. ▮

Archaeology

Vast Bronze Age city discovered on the plains of Kazakhstan

Chris Simms

A LARGE 140-hectare settlement dating back 3600 years has been discovered in north-eastern Kazakhstan, transforming our understanding of life in prehistoric Eurasia. It hints that the open grasslands of Central Asia once held a Bronze Age community as connected and complex as much better-known ancient civilisations.

"It's not quite a missing piece of the jigsaw; it's the missing half of the jigsaw," says Barry Molloy at University College Dublin, Ireland, who wasn't involved in the work.

The Bronze Age featured many notable civilisations, including the Shang and Zhou dynasties in China; the Babylonians and Sumerians in what is now Iraq; and numerous cultures around the Mediterranean, including the Egyptians, Minoans, Mycenaeans and Hittites.

The Central Asian steppes, however, were thought to be the domain of highly mobile communities living in tents or yurts. Semiyarka, or the "City of Seven Ravines", seems very different and could have played a crucial role in the spread of bronze items among civilisations.

This is because the site – first identified in the early 2000s – overlooks the Irtysh river, which rises up in the Altai mountains in China, comes down onto the plains of Kazakhstan and goes all the way to the Arctic through Siberia.

Miljana Radivojević at University College London and her colleagues have been mapping and surveying the site since 2016. They have discovered that Semiyarka featured long banks of earth, conceivably for defence; at least 20 enclosed household compounds, probably built with mud bricks; and a central monumental building, which they suggest might have been used for rituals or governance. The types of pottery found there indicate the site dates to around 1600 BC (*Antiquity*, doi.org/qfdk).

PETER J. BROWN

An aerial view of the archaeological site of Semiyarka

Crucially, the crucibles, slag and bronze artefacts at the site indicate a large area was dedicated to the production of copper and tin bronze – an alloy that is mainly copper but contains more than 2 per cent tin.

Compositionally, the elements in the slag from the crucibles correspond to tin deposits from part of the Altai mountains in east Kazakhstan about 300 kilometres away, says Radivojević.

V.K. MERZ AND I.K. MERZ

Many bronze artefacts were discovered at Semiyarka

The tin may have been brought there by people traversing the steppes or by boat along the Irtysh, or it may have been panned from the water, she says. "The Irtysh is the most important tin-bearing river in the Bronze Age of Eurasia and the flooding of the river's flood plain that was happening seasonally would have been very helpful for panning the tin."

Due to its position on the river near major copper and tin deposits, the researchers suggest Semiyarka wasn't only a production hub for bronze, but also a centre of exchange and regional power, a key node in the vast Bronze Age metal networks linking Central Asia with the rest of the continent.

The site transforms our understanding of Bronze Age steppe societies, says Radivojević, showing that they were just as sophisticated as other contemporaneous civilisations. ▮

Health

Tablets could one day replace weight-loss injections

Carissa Wong

A DAILY pill may offer an alternative to Wegovy and Ozempic injections after a trial found it led to substantial weight loss and improved blood sugar levels in people with obesity and type 2 diabetes.

Orforglipron, developed by pharmaceutical company Eli Lilly, is designed to work in the same way as semaglutide, the active ingredient in Wegovy and Ozempic, which mimics a hormone called GLP-1.

A prior trial found that orforglipron enabled people with obesity but without type 2 diabetes to lose about 11 per cent of their body weight, on average, over 72 weeks. This is less than the 15 per cent typically achieved over a similar period with injectable semaglutide, but taking medication as a pill is more convenient, says Deborah Horn at the University of Texas.

To explore whether people with obesity and type 2 diabetes could also benefit, she and her colleagues randomly assigned about 900 out of 1600 participants to take either a low, medium or high dose of orforglipron daily. The rest took a placebo, and they all received lifestyle advice.

After 72 weeks, those on the high dose had lost nearly 10 per cent of their body weight, on average, with 67 per cent of them losing more than 5 per cent. The medium- and low-dose groups lost roughly 7 per cent and 5 per cent, on average. Those on the placebo lost less than 3 per cent (*The Lancet*, doi.org/qfhv).

People taking the high dose also saw a reduction in their blood sugar levels of nearly 2 per cent, on average.

About a tenth of the participants on the high and medium doses had to stop taking the drug due to side effects such as nausea and diarrhoea, which was about twice the rate seen for low-dose and placebo. But most found the side effects manageable, says Horn. ▮

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Physics

Twist on 1845 experiment rewrites link between light and magnetism

Karmela Padavic-Callaghan

IN 1845, physicist Michael Faraday provided the first direct evidence that electromagnetism and light are related. Now, it turns out this connection is even stronger than Faraday imagined.

In his experiment, Faraday shone light through a piece of glass that was laced with boracic acid and lead oxide and immersed in a magnetic field. He discovered that this altered the light: when it emerged from the glass, its polarisation had been reorientated.

Light is an electromagnetic wave, and for the past 180 years it has been widely accepted that this "Faraday effect" demonstrates that the combined interaction of the magnetic field, the electric charges in the glass and the electric component of light results in the light wave becoming rotated – wiggling in a different direction than before it entered the material.

Perhaps surprisingly, it has long been assumed that the magnetic component of light plays effectively no role in the Faraday effect. Amir Capua and Benjamin Assouline at the Hebrew University of Jerusalem have now shown that this isn't necessarily always the case.

"There is a second part of light that we now understand interacts with materials"

"There is a second part of light that we now understand interacts with materials," says Capua.

He says there are two reasons why researchers didn't pursue the idea that the magnetic component of light plays a part in the Faraday effect. Firstly, the magnetic forces within materials like Faraday's glass seem to be relatively weak compared with the electric forces. Secondly, when such materials are magnetised – which means the quantum spins of their constituent parts interact with any magnetic field like tiny magnets would – these spins are typically out of sync with the magnetic component of the light waves, which suggests the two don't interact strongly.

But Capua and Assouline realised that when the magnetic component of light is circularly polarised – essentially swirly or corkscrew-like – it can interact with the magnetic spins in the glass a lot more intensely. They concluded that this happens even without any special effort to manipulate the light, because its magnetic component is always made up of several corkscrew waves.

Their calculations revealed that if Faraday's experiment is repeated with a magnetic material called Terbium Gallium Garnet (TGG) instead of glass, this magnetic interaction could actually account for 17 per cent of the resulting Faraday effect when visible light passes through the material (*Scientific Reports*, doi.org/hbbwkd). If infrared light is passed through the TGG material instead, the magnetic interaction would account for as much as 70 per cent of the resulting Faraday effect.

Igor Rozhansky at the University of Manchester, UK, says the new calculations are convincing and point towards plausible experimental tests in the future. The so-far neglected magnetic component of the Faraday effect could provide a new way for researchers to manipulate spins inside materials, he says. ▮

Ancient humans

Neanderthals may not have had a nose for the cold after all

THE first analysis of a well-preserved nasal cavity in the human fossil record has revealed the hefty Neanderthal nose wasn't adapted to cold climates in the way many people thought it was.

Neanderthals (*Homo neanderthalensis*) lived between about 400,000 and 40,000 years ago, and some specimens have been found with distinct structures in their nasal cavities that have been proposed as defining features for the species. Some researchers have suggested that living through repeated glacial conditions led them to develop these structures to adapt to cold weather, helping them warm up inhaled air inside their noses.

However, good fossil evidence for the complete picture within the Neanderthal nose has been lacking.

Costantino Buzi at the University of Perugia in Italy and his colleagues have now got such evidence from a Neanderthal specimen known as Altamura Man, which is between 172,000 and 130,000 years old. The skeleton is embedded in rock in Lamalunga cave near the town of Altamura in southern Italy and is peppered with what are known as popcorn concretions – small nodules of calcite – that give it the appearance of a coral reef.

"It's probably the most complete human fossil ever discovered," says Buzi. The delicate specimen can't be removed, so Buzi and his colleagues took their equipment through the narrow parts of the cave and used an endoscope to peer inside the skull, allowing them to digitally reconstruct its well-preserved internal nasal bony structures (*PNAS*, doi.org/hbbsvx).

K.A.R.S.T. PRIN PROJECT

The skull of Altamura Man, a Neanderthal skeleton embedded in rock

Surprisingly, there was no sign of the inner nasal features thought to be defining to Neanderthals, such as a ridge of bone known as a vertical medial projection, and a lack of a bony roof over the lacrimal groove.

But Altamura Man is undoubtedly a Neanderthal, according to its general morphology, dating and genetics, says Buzi. This means these nasal structures should no longer be considered defining Neanderthal features, he says, and the large nose and jutting-out upper jaw are unlikely to have been shaped by them. "We can finally say that some traits that were considered diagnostic in the Neanderthal cranium do not exist," says Buzi.

However, they did find that the turbinates – scroll-like structures on the walls of the nasal cavity – are quite big, which would help warm the air inside. ▮

Chris Simms

Human behaviour

Kissing may be millions of years old

Neanderthals and other hominins probably kissed, perhaps to promote bonding or assess mates

Chris Simms

EARLY humans may have kissed, and our ape ancestors could have done so as far back as 21 million years ago.

There is wide debate over when humans began kissing romantically. Ancient texts hint that sexual kissing was practised in ancient Mesopotamia and Egypt at least 4500 years ago, but because such kissing has been documented in only about 46 per cent of human cultures, some argue it is a cultural phenomenon that emerged relatively recently.

However, there are hints that Neanderthals exchanged oral bacteria with *Homo sapiens*, and chimpanzees, bonobos and orangutans have all been observed kissing.

To look for answers, Matilda Brindle at the University of Oxford and her colleagues have attempted to work out the evolutionary history of kissing.

They first came up with a definition of kissing that would work across many species, settling on mouth-to-mouth contact that is non-antagonistic and involves movement of the lips, but not the transfer of food.

This leads to many smooches being excluded, including kisses elsewhere on the body. "If you kiss someone on the cheek, then I would say that is a kiss, but by our definition, it isn't kissing," says Brindle. "Humans take kissing to a new level."

The team then searched the scientific literature and contacted primate researchers to seek out reports of kissing in modern monkeys and apes that evolved in Africa, Europe and Asia.

There is wide debate over when humans began kissing romantically

To estimate the likelihood that various ancestral species engaged in kissing, Brindle and her colleagues mapped out this information in a family tree of primates and ran a statistical approach called Bayesian modelling 10 million times to simulate different evolution scenarios.

They found that kissing probably evolved in ancestral apes some 21.5 million to 16.9 million years ago and there is an 84 per cent chance that our extinct human relatives, Neanderthals, engaged in kissing too (*Evolution and Human Behavior*, doi.org/qffc).

NIKOLAY VINOKUROV/ALAMY

There isn't enough data to tell why kissing evolved, says Brindle, but she suggests two hypotheses. It could enhance reproductive success either by promoting arousal, or by letting animals assess mate quality. "If someone has bad breath, then you can choose not to reproduce with them," she says.

Another idea is that non-sexual kissing developed from grooming and is useful for strengthening bonding and mitigating social tension. "Chimpanzees will literally kiss and make up after a fight," says Brindle.

"I think from the evidence that they have, kissing definitely has this affiliative function," says Zanna Clay at Durham University, UK. "We know, for example, in chimps that it does seem to form this important role in repairing social relationships. But to me, the sexual aspect is a little bit of a question mark."

Technology

Mosquito mouthpart could help us make better 3D printers

A SEVERED mosquito proboscis can be turned into an extremely fine nozzle for 3D printing, and this could help create replacement tissues and organs for transplants.

Changhong Cao at McGill University in Montreal, Canada, and his colleagues developed the technique, which they call 3D necroprinting, because they were unable to find nozzles thin enough for their work on manufacturing very fine structures.

"This made us think whether there is an alternative," says Cao. "If Mother Nature can provide what we need with an affordable cost, why make it ourselves?"

The researchers tasked graduate student Justin Puma with finding a natural organ that could handle the task, considering everything from scorpion stingers to snake fangs. They eventually found that a mosquito proboscis – in particular, the stiffer version found in female Egyptian mosquitoes (*Aedes aegypti*) – allowed them to print structures as thin as 20 micrometres across (*Science Advances*, doi.org/hbb24g).

Cao says an experienced worker can make six nozzles an hour from mosquito mouthparts at a cost of less than a dollar each, making the process easy to scale up. The natural nozzles can be fitted to existing 3D printers and are relatively long-lasting: after two weeks, around 30 per cent of them begin to fail, but they can be stored frozen for up to a year.

"If Mother Nature can provide what we need with an affordable cost, why make it ourselves?"

The team tested the technique using a bio-ink called Pluronic F-127, which can build scaffolds for biological tissues including blood vessels – a potential method for creating replacement organs.

Christian Griffiths at Swansea University, UK, says this is another example of human engineers struggling to match the tools developed by nature.

"You've got a couple of million years of mosquito evolution: we're trying to catch up with that," he says.

Matthew Sparkes

Botany

Moss spores survive space exposure

James Woodford

ON 4 March 2022, astronauts locked 20,000 moss spores outside the International Space Station for 283 days. They then rescued the spores and returned them to Earth on a SpaceX capsule so that scientists could try to germinate them. Surprisingly, these attempts were successful.

Mosses were among the earliest land plants and are well known for colonising some of Earth's harshest environments. "We wondered whether their spores might also survive exposure to outer space – one of the most extreme environments imaginable," says team member Tomomichi Fujita at Hokkaido University in Japan.

Numerous studies have already simulated whether various mosses can survive beyond Earth. But this is the first time researchers have tested whether a species of moss can cope with real space conditions. The spores came from the species *Physcomitrium patens*.

A control group of spores that had stayed on Earth had a germination rate of 97 per cent, as did another set of spores that were exposed to space but shielded from the damaging ultraviolet radiation.

Most astonishingly, over 80 per cent of the spores that were exposed to the full brunt of space remained viable and germinated into normal plants (*iScience*, doi.org/qfht). The team predicts that, based on the results of these experiments, some of the spores could remain viable in space for 15 years.

283

How many days the spores spent locked outside the ISS

Prior to the deployment, researchers tested other living parts of the moss, such as its filaments, in simulated conditions. They found that other life stages of the moss succumbed to UV radiation, freezing and heating, high salinity and dehydration within days to weeks. But the spores seemed to be able to cope with all these challenges.

Fujita says the multiple layers of spore walls that encase the reproductive tissue appear to offer "passive shielding against space stresses". This might have been an adaptive feature they developed to cope with the harsh conditions on land when life first moved out of the oceans.

While the research doesn't in any way prove that extraterrestrial life exists, it strengthens the case that life, once it has emerged, can be incredibly robust, says Fujita.

David Eldridge at the University of New South Wales in Sydney says the true test is whether the spores can also germinate in space. "The trick will be to check the growth rates of these taxa in space and see whether they can reproduce," he says. ▮

This moss grew from a spore that was exposed to space for nine months

TOMOMICHI FUJITA

Climate change

Arctic Ocean is now warming from below

Alec Luhn

PETER ORR PHOTOGRAPHY/GETTY IMAGES

Sea ice in the Arctic has been shrinking

WARMER Atlantic water from near Greenland is heating up the depths of the Arctic Ocean, one of the few places thought to be largely unaffected by climate change.

Sea ice floating on the Arctic Ocean has shrunk by about 40 per cent in four decades, due largely to the effect of atmospheric warming on the ocean surface. Now, a team from the Ocean University of China has analysed new measurements to estimate warming at the bottom of the ocean.

In the Eurasian basin, one of the ocean's two major basins, the waters between 1500 and 2600 metres deep have warmed by 0.074°C since 1990 (*Science Advances*, doi.org/qfcv).

This represents the transfer of almost 500 trillion megajoules of energy. If that amount of energy were present at the surface, it could melt as much as a third of the minimum sea ice extent.

"I thought the deep ocean could be warming, but not so fast," says Xianyao Chen, a member of the research team.

An underwater mountain range running between Greenland and Siberia divides the Arctic Ocean into its two basins. While the Amerasian basin is largely walled off from the Pacific by the shallow Bering Strait, an extension of the Atlantic Meridional Overturning Circulation brings warm Atlantic water northwards along the coast of Scandinavia and into the upper layers of the Eurasian basin. As seawater freezes in the winter, the salt in it is ejected from the crystals. This forms dense water that sinks to the depths, taking some warm water from the Atlantic with it.

The geothermal heat of Earth also warms deep water in the Eurasian basin.

Previously, the warming was offset by an influx of cold deep water from the basin immediately to the east of Greenland. But as the Greenland ice sheet melts, more freshwater has entered the Greenland basin. This has slowed the sinking of cold, salty water to the deep and helped raise the deep water temperature from -1.1°C to -0.7°C. As a result, the movement of this Greenlandic deep water into the Arctic Ocean no longer cancels out these warming processes. ▮

Environment

More of us are living in urban areas than we first thought

Carissa Wong

TOMOHIRO OHSUMI/GETTY IMAGES

City life has an effect on the environment and our health

FOUR-FIFTHS of the world's population now live in towns and cities, according to a major United Nations report, and this figure is set to rise further, underscoring the need to ensure urban areas benefit both our health and the planet.

The most recent edition of the World Urbanisation Prospects report, published in 2018, found that 55 per cent of people live in urban areas, but that estimate relied on countries' widely varying definitions of what constitutes an urban or rural settlement. For instance, Denmark defines urban areas as those inhabited by as few as 200 people, but this figure is 50,000 in Japan.

To gain a clearer picture, Sara Hertog at the UN in New York and her colleagues defined urban areas as either cities inhabited by at least 50,000 people, with at least 1500 individuals per square kilometre, or towns with at least 5000 inhabitants and a density of at least 300 people per km^2.

Next, they analysed satellite and national survey data from 237 countries and regions to estimate the degree of urbanisation globally in 2025. This revealed that 45 per cent of the world's population now live in cities, mostly in those with fewer than 250,000 people, while 36 per cent live in towns – meaning 81 per cent of people are urban-dwellers. The remaining 19 per cent live in rural regions.

81%

How many people now live in towns and cities worldwide

Using a statistical model that accounted for factors like population ageing and migration trends, the team also estimated that by 2050, 83 per cent of people globally will live in urban, rather than rural, regions.

The fresh estimates will help the UN assess progress towards its 11th sustainable development goal, which aims to "make cities and human settlements inclusive, safe, resilient and sustainable" by 2030, says Hertog. The results will also help shape policies to reduce global warming by feeding into reports produced by the Intergovernmental Panel on Climate Change, she says.

The drivers of urban population growth vary between regions. In eastern and southern Asia, it is mainly driven by people migrating from rural to urban areas within countries, says Hertog. "People move in search of education and employment, but also social life," she says. In Europe and North America, international migration plays a large role, while in sub-Saharan Africa, it is mainly down to birth rates exceeding deaths, she says.

Increasing urbanisation can either benefit or harm the environment. For instance, if a city expands its borders due to population growth, but public transport links aren't planned appropriately, this can lead to urban sprawl, where people rely heavily on cars – increasing emissions, says Hertog. However, careful planning can provide transportation that is more energy-efficient than in rural regions, she says.

Urbanisation also has health effects. For instance, people are generally more exposed to air pollution and extreme heat in cities, both of which have been linked to worse cardiovascular health and seem to raise the risk of conditions like Alzheimer's disease, says Andrea Mechelli at King's College London.

But urbanisation can bring health benefits. "Healthcare is more responsive; it's more comprehensive in cities compared to rural areas," says Mechelli. ▮

Space

Strange structure found at the edge of the solar system

Leah Crane

THE Kuiper belt, a disc of icy rocks on the outermost edges of the solar system, seems to have more structure than we thought. In 2011, researchers found a cluster of objects there on similar orbits that they named the "kernel" of the Kuiper belt. Now, another team has spotted an even more compact cluster of objects, dubbed the "inner kernel".

The original kernel was found by eye using plots of the orbits of 189 Kuiper belt objects (KBOs). It is about 44 astronomical units from the sun, where 1 astronomical unit is the distance between the sun and Earth.

Since the discovery of the kernel, no additional structures have been found in the Kuiper belt – that is, until Amir Siraj at Princeton University in New Jersey and his colleagues took on the painstaking task of refining the orbital data from 1650 KBOs and feeding it into an algorithm that searches for clustering and structure. They trained the algorithm to search for the kernel and examined the results to see if there were any more structures out there. "The kernel was never found alone – whenever the algorithm found the kernel, it found another group as well," says Siraj.

The team called this newfound cluster the inner kernel because of its location about 43 astronomical units from the sun (arXiv, doi.org/qfcw). All of the objects in the inner kernel have remarkably circular orbits, almost completely in line with the disc of the solar system.

"That kind of orbital calmness is a signal of a very old, undisturbed structure – the kind of structure that can provide clues to the evolution of the solar system," says Siraj.

The Vera C. Rubin Observatory in Chile, which began operations this year, is expected to find many more KBOs, which should tell us whether there are any other undiscovered structures on the solar system's edge. ▮

Quantum computing

Recycling qubits gets results

Reusing the basic components of quantum computers makes them more reliable

Karmela Padavic-Callaghan

QUANTUM computers made from qubits based on extremely cold atoms have been getting larger at an impressive rate, which may soon make them computationally powerful. Now, researchers have worked out how to replenish and reuse those qubits, which are the building blocks of quantum computers, to make their computations more practical and reliable.

Existing quantum computers are too error-prone to tackle computations that are both useful and give them an edge over traditional computers, but researchers have made strides in developing error-correction schemes that could resolve this.

In one such scheme, qubits are split into two key groups: those tasked with manipulating data and running computations, and others called "ancilla qubits", which keep track of errors.

Creating many high-quality qubits for either purpose is a big technical challenge, so Matt Norcia at Atom Computing in the US and his colleagues have devised a way to reuse or replace ancilla qubits, cutting down on the number they need to make. They have now shown their error-tracking qubits can be recycled 41 times in a row (*Physical Review X*, doi.org/qd9x).

"Any computation of use is likely to be a very long computation, so you'd have to do many rounds of measurements. Ideally, you want to be able to reuse the qubits throughout multiple rounds so that you don't have to continue providing more qubits into the system," says Norcia.

He and his colleagues used qubits made from electrically neutral ytterbium atoms cooled to temperatures close to absolute zero with lasers and electromagnetic pulses. They could control the quantum state and the quantum properties that encode information for each atom with lasers configured into "optical tweezers". The team used this technique to organise their quantum computer into three different zones.

"Without this capability, even modest calculations would require millions or billions of qubits"

In the first zone, 128 optical tweezers directed qubits to run computations, while in the second zone 80 tweezers held qubits that could be used for error measurements or swapped in place of erroneous qubits. The third zone acted as storage, holding space for 75 more qubits that were just freshly put into a useful state. Having these last two zones enabled the researchers to either reset and reuse ancilla qubits or swap them out for new ones.

Because any stray light from one laser that touches a nearby qubit can disturb its function, the team had to develop precise control over their lasers and also ways to tune the states of the data qubits so they remain "hidden" from or unbothered by certain types of light, says Norcia.

"Ancilla reuse is fundamentally important for quantum computing progress," says Yuval Boger at US quantum computing company QuEra. Without this capability, even very modest calculations would require millions or billions of qubits, which is not plausible for any existing or soon-to-be-built quantum computing hardware, he says. ▮

Archaeology

Ancient figurine may show goose mating with a woman

A TINY, 12,000-year-old clay sculpture of a goose on the back of a woman may depict an imagined animistic ritual involving a gander mating with a human.

The sculpture, which is just 3.7 centimetres tall, was collected in 2019 at an archaeological site called Nahal Ein Gev II near the Sea of Galilee, but its significance wasn't recognised until 2024.

Nahal Ein Gev II was inhabited by a group of Palaeolithic hunter-gatherers called the Natufians, who had established permanent settlements in the region.

While the elements of the figurine can be hard for the untrained eye to distinguish, Laurent Davin at the Hebrew University of Jerusalem says he is "100 per cent confident" that it is a goose on the back of a woman (*PNAS*, doi.org/qd8w). Davin says the object is the "earliest human-animal interaction figurine" ever discovered.

LAURENT DAVIN

The 12,000-year-old sculpture that might depict a woman and a goose next to a reconstruction

Geochemical tests revealed that the figurine had been heated to around 400°C. The artist had meticulously modelled the clay with an understanding of both anatomy and how light and shadow would accentuate the scene being captured by the artist, says Davin.

"We interpreted the scene as the depiction of the imagined mating between an animal spirit and a human," he says. "This theme is very common in animistic societies across the world in specific situations such as erotic dreams, shamanistic visions and myths."

They also identified a fingerprint on the figurine, most likely made by the artist. Its small size meant it must have belonged to either a young adult of either sex or an adult female.

Paul Taçon at Griffith University in Brisbane, Australia, thinks there is another possible interpretation.

"It may be that a story about a woman being attacked by a goose was represented... but we will never really know the exact meaning." ▮

James Woodford

URGENT MEDICAL RESPONSE

MEDECINS SANS FRONTIERES
DOCTORS WITHOUT BORDERS

HELP SUPPORT OUR MEDICAL TEAMS TODAY

Al-Shifa hospital in Gaza City is one of many health facilities in Gaza that have been severely damaged or destroyed since the start of the war. Photo: Nour Alsaqqa/MSF

NADIA EID IS PART OF THE MSF MEDICAL TEAM IN GAZA

The level of destruction here is hard to describe. Gaza is in mountains of rubble.

Most people in Gaza don't have access to clean water. They don't have access to food or sanitation. Even though a ceasefire was declared on October 10, almost no one got to go back to their houses because those houses no longer exist. People are still living in tents. The situation is catastrophic.

There are many people who are not only living in these inhumane conditions but have also sustained life-changing injuries from explosions or gunshots. I feel so much for the children who have lost limbs, who have amputated legs or arms. They need ongoing treatment and care, but the health system has almost collapsed.

A lot of hospitals and clinics have been directly targeted in the bombardments. MSF teams are currently working at healthcare centres and hospitals across Gaza, but many are either constructed from tents or are using tents as additional wards.

We are seeing hundreds of patients on a daily basis, but each day at our health centres there are more people than we can treat and some have to be turned away.

It's very difficult for us that we have to face this, but this is the reality. People need care now and it will take years to rebuild Gaza's medical facilities.

We don't know what will happen next. I hope we will actually reach the end of this war. But even if that happens, the suffering continues.

MSF has over 1,000 staff in Gaza providing medical care, managing supplies and working on clean water and sanitation. But right now, it's not enough. We don't have the resources to treat every patient. The humanitarian response here must be massively scaled up. More help is urgently needed.

"MSF's ability to act quickly and decisively in emergency situations is made possible by individual donors giving what they can"

Dr Jennifer Hulse, MSF Emergency Doctor

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THANK YOU

MSF UK receives no government funding. It's your support that enables us to provide medical care where it's needed most.

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MSFR0048

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The rescue mission to free a chained-up humpback whale p26

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Our pick of the best science books of 2025 p28

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This year's top sci-fi novels, from deep space to dystopia p30

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Why survival of the nicest really does make sense p33

Comment

(Re)making memories

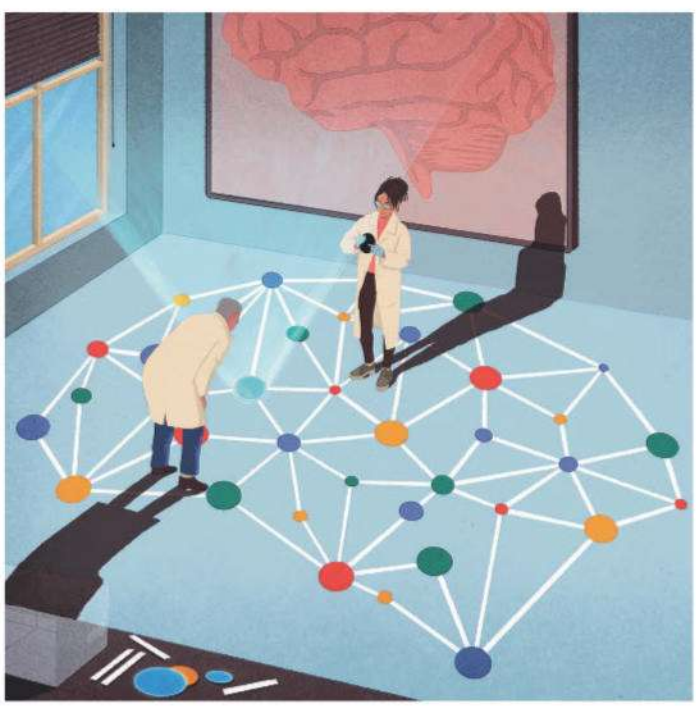
Memory manipulation might sound like dystopian science fiction, but it could be one of humanity's healthiest ideas, says **Steve Ramirez**

WHEN my late lab partner Xu Liu and I first illuminated the brain cells that stored a particular memory, it felt like watching a thought flicker back to life. We stimulated a constellation of neurons inside a mouse's hippocampus and hypothesised that these very neurons were the physical basis of memory, or the engram. We didn't realise we were stepping into one of the most exciting frontiers in neuroscience: the ability to edit memory itself.

The phrase "memory manipulation" sounds sinister, conjuring up dystopian visions of erased histories or implanted lies. But in the lab, the reality is gentler and far more hopeful. The same discoveries that let us toggle memories on and off in mice are teaching us how to heal the brain from within, including how to weaken traumatic recollections, strengthen fading ones and rebalance the emotions that our memories carry.

Over the past decade, this work has revealed three broad principles. First, memories are malleable when they are being stored, recalled and restored. Second, they are distributed across the brain rather than in one region. And third, they can be artificially etched into the brain. Each principle reframes what "editing memory" really means.

When we form a memory, brain cells fire together and strengthen their connections. That process can be enhanced or impaired with different patterns of stimulation. Brain stimulation with implanted electrodes or magnetic pulses can improve navigation through virtual environments. Drugs, hormones or even a bit of sugar can enhance the brain's ability to stabilise new experiences. And exercise stimulates the growth of new neurons and improves the health of our hippocampus, the rest of the brain and the body. The same idea works in reverse. Overstimulate memory circuits and a memory's strength dims; block the molecules that cement those connections and it weakens more.



SIMONE ROTELLA

Memories can also be modified when recalled, temporarily destabilising a memory and opening a window of opportunity before it is stored again. Therapists already use this "reconsolidation window" when helping people living with phobias or trauma. In our animal studies, repeatedly reactivating negative memories is enough to blunt their emotional charge. What's more, reactivating positive memories during distress can overwrite the negative tone entirely. In mice, a week of "positive memory reactivation" reversed depression-like behaviours for over a month.

Because memories are spread across the brain, they are also remarkably resilient. Damage to one region rarely deletes an entire experience. Instead, the brain can reroute access through alternate pathways and call upon multiple "drafts" of the memory. This redundancy offers hope for treating Alzheimer's: if we can strengthen still-intact routes to a memory, we may repair pieces of identity once thought lost. Memory manipulation, then, isn't about rewriting who we are – it is about giving the brain new paths back to itself.

The idea raises ethical concerns, as every major medical advance, from pacemakers to transplants, once did. The goal of our work is to reduce suffering and thereby improve our collective well-being: to help a veteran loosen the grip of a flashback, someone in recovery decouple a craving from its trigger, or someone with Alzheimer's hold on to the names of loved ones.

Learning to reshape memory responsibly can help us heal, and the brain already edits memories every time we revisit them. Science today is simply learning the rules. And when I think about flickering memories on with Xu, I don't see science fiction. I see science fact and a future in which remembering becomes a medicine for the mind. ▮

JANICE CHECCHIO

Steve Ramirez is author of *How to Change a Memory: One neuroscientist's quest to alter the past*

Field notes from space-time

A trip to the dark side

We can't see dark matter directly, so studying it pushes the boundaries of our creativity as scientists. How exciting, says **Chanda Prescod-Weinstein**

Chanda Prescod-Weinstein is an associate professor of physics and astronomy at the University of New Hampshire. She is the author of *The Disordered Cosmos* and the forthcoming book *The Edge of Space-Time: Particles, poetry, and the cosmic dream boogie*

Chanda's week

What I'm reading
I have just finished Addie E. Citchens's astonishing debut novel, Dominion.

What I'm watching
I recently caught up on the summer episodes of Emmerdale *and HOLY SMOKES!*

What I'm working on
My collaborators and I have some fun new research ideas about dark matter scenarios.

This column appears monthly

NOW is a surreal time to be a dark matter researcher. Even as research funding is being cut by governments around the world, dark matter remains one of the biggest and most exciting open problems in all of physics – in all of science, frankly. Most of the matter in the universe appears to be invisible: for every kilogram of visible matter, there are apparently 5 kilograms of dark matter. We know this only because we have seen the impact of dark matter on how the visible elements of the universe are structured.

Clusters of galaxies are best explained when dark matter is a presumed component. Observations of the distribution of the earliest free-flying light in the universe only match our theoretical predictions if dark matter is part of the model. A host of other observations confirm the same: there is a lot of dark matter, invisible to us unless we look for how it shapes visible matter.

As we enter the second half of the 2020s, it is an incredibly exciting time for dark matter research. The European Space Agency's Euclid space telescope's work will lead to a better understanding of galaxy structure. In tandem, the Vera C. Rubin Observatory is just beginning a 10-year survey of the sky, and it will almost certainly transform our knowledge of the satellite galaxies that live in the orbit of larger companions. These dynamics will help us map out how dark matter governs visible matter in more detail.

To study something that we know is out there but we can't see directly is to push the boundaries of our creativity as scientists. Among the questions we have to ask and try to creatively answer are: How shall we look for it? Can we capture a dark matter particle in the lab? How do we study its properties if we can't?

The only way out is through. We have to start with what we do know and try to grow our knowledge from there. We are fairly confident that dark matter is matter-like, suggesting we can use the same mathematical tools to study it that we use to study ordinary particles, such as quantum field theory (QFT).

QFT sounds complicated – and it is – but a non-expert can still get a feel for it. It is perhaps our most fundamental theory of physics, since it combines special relativity and quantum mechanics (but not general relativity). The idea behind it is that throughout the universe, the potential for a particle to be created exists at each point, due to the presence of a field associated with that particle type.

> "Increasingly, we are now looking for evidence of dark matter scattering off electrons, not just hitting a target"

Think about strawberry fields. The strawberries only manifest in some places, not others. This is due to the specific properties of those points in space-time – they are the places where the right conditions exist for a strawberry flower to blossom. The potential for strawberries is everywhere in a strawberry field, but only in some places will they actually come to be. In a loosely similar fashion, this is how QFT tells us particles come into existence.

QFT is a tough subject that even experts spend many years really developing a feel for. And even if we think it is sensible to apply QFT to dark matter in order to make some smart guesses about it, there comes the question of how we could write down equations to describe something whose properties mostly elude us.

From a sociological standpoint, it is quite fun to see the myriad ways scientists have responded to this question. Over the past decade or so, one popular approach to characterising things we don't know is to develop an "effective field theory" (EFT). EFTs are a neat way of writing down a generalised set of equations with characteristics that can be tuned depending on observations.

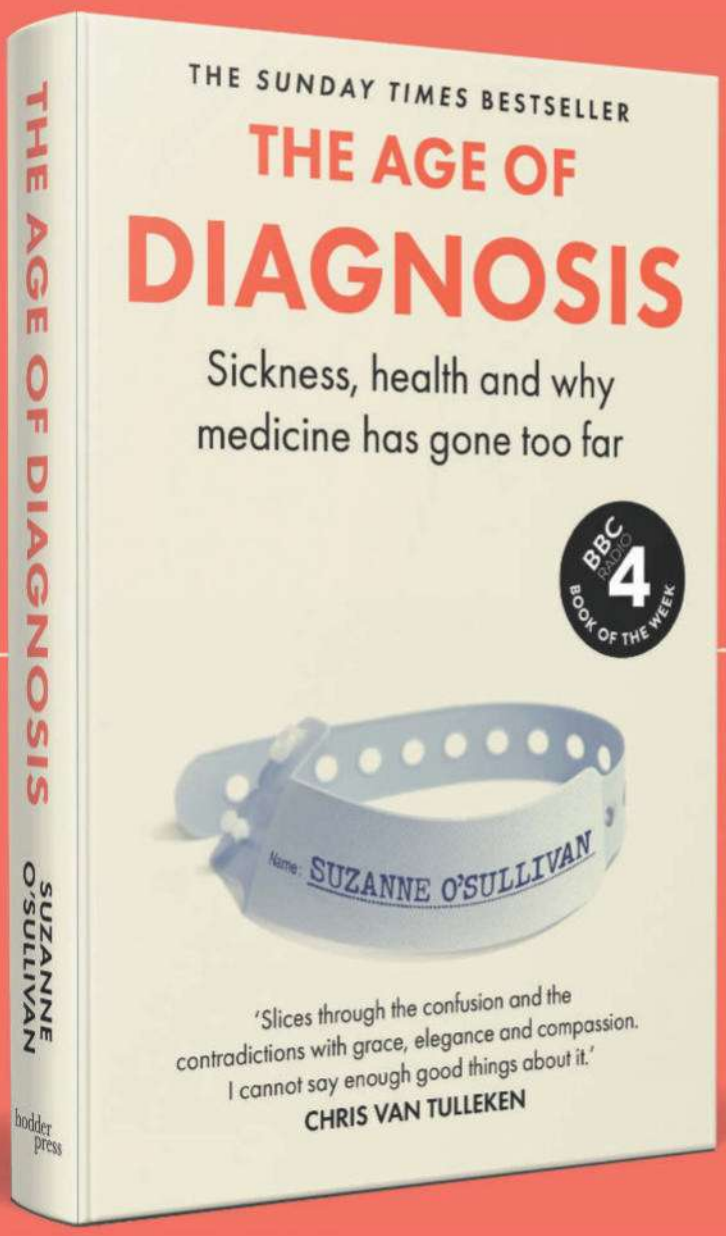
EFTs can also be developed with a particular experimental framework in mind. For example, one important way we attempt to understand dark matter is through direct detection experiments. With these, we hope that some kind of interaction between dark matter and visible matter will yield an effect that is observable in a terrestrial experiment. Over the years, direct detection approaches have matured and multiplied. Instead of just looking for evidence of dark matter hitting a target, increasingly we are now looking for signs of dark matter scattering off electrons. This experimental shift means EFTs must evolve alongside it.

In a preprint paper published this month, researchers Pierce Giffin, Benjamin Lillard, Pankaj Munbodh and Tien-Tien Yu propose an EFT that can better account for these scattering interactions. While the paper has yet to go through peer review, it caught my attention because it is a great example of work that might never be front-page news, but nonetheless is exactly the sort of thing that drives research forward. Science requires patience, and I hope our leaders remember that. ▮

IS A DIAGNOSIS ALWAYS THE ANSWER?

'Revelatory'
Chris Van Tulleken

'Fascinating'
The Times

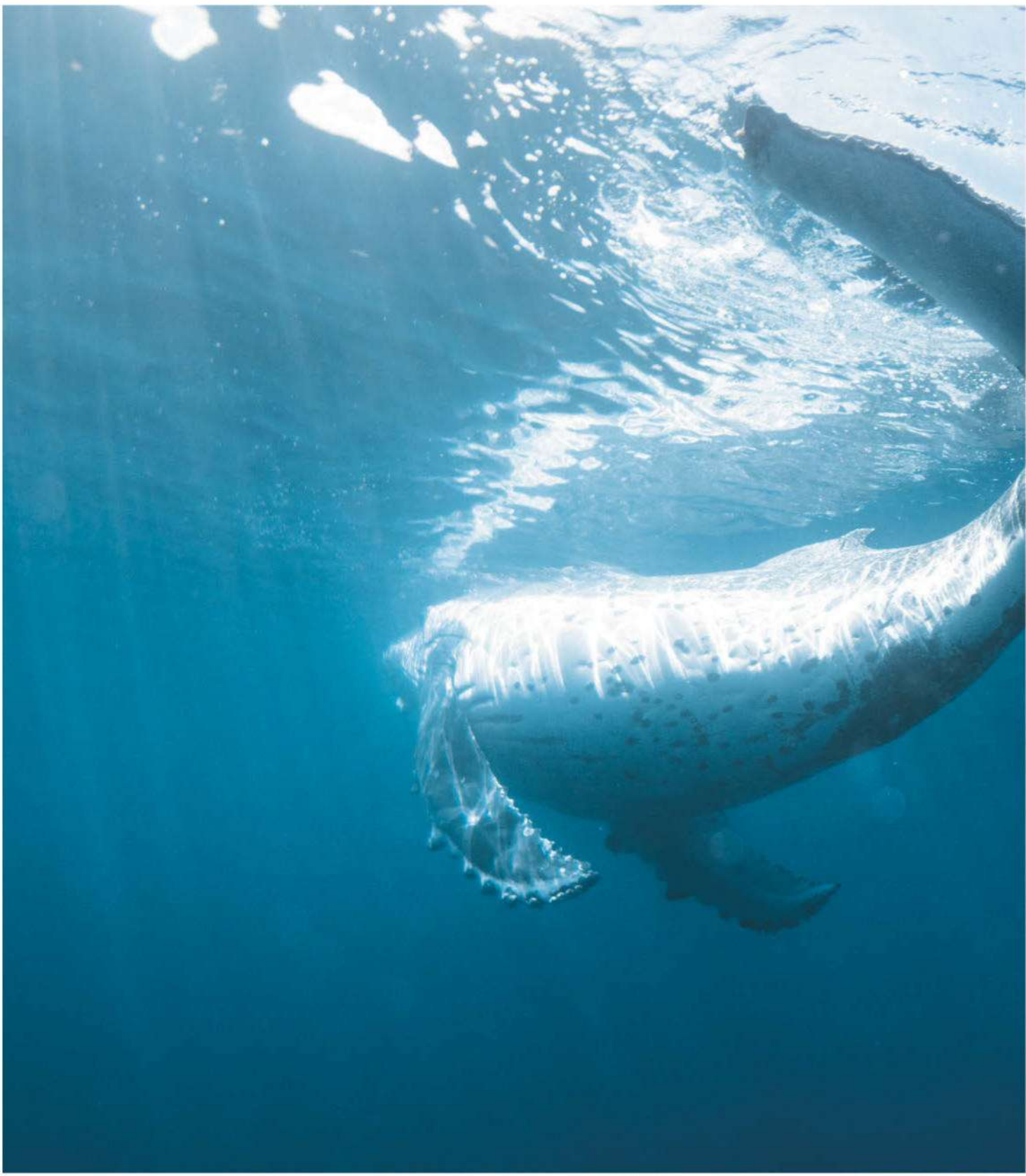


'Brave'
Financial Times

'Outstanding'
Guardian

A moving and eye-opening journey through modern illness from neurologist Suzanne O'Sullivan

A WATERSTONES 'BEST BOOKS OF 2025'



MIESA GROBBELAAR/TNC 2025 OCEANIA PHOTO CONTEST

Rescue mission

The Nature Conservancy 2025 Oceania Photo Contest

JUST moments after Miesa Grobbelaar photographed this female humpback whale being freed from a chain, the whale "paused and looked at us, as if saying thanks", she said.

The picture of the rescue effort, which was taken near the coast of Ha'apai, Tonga, won the grand prize in the Nature Conservancy's 2025 Oceania Photo Contest.

Grobbelaar and her team of rescuers had answered a distress call about an entangled humpback whale, arriving to find a "heavy rusted chain cutting deep into her tail", said the photographer in a statement announcing her win. They worked "carefully and silently" to free her, until the chain finally snapped and the whale looked at its rescuers, she said.

While humpback whales as a species are no longer considered endangered, with overall numbers having recovered from low levels seen in the mid-20th century due to excessive whaling, there are still some populations at risk, including those found off the coast of Tonga. These still number in the low thousands, which is around 30 per cent lower than before widespread whaling.

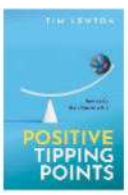
Jarrod Boord, one of the competition's judges, described the winning image as "horrific and beautiful" in the statement. "It's humanity's relationship with nature at its worst and humanity caring for nature at its best, all at the same time," he said.

The Oceania Photo Contest was open to photographers from Australia, New Zealand, Papua New Guinea and the Solomon Islands.

Alex Wilkins

Reading the highlights

Women's hidden extra work, positive tipping points and new thinking on autism – there's much to chew on in this year's best reads, says **Liz Else**



***Positive Tipping Points: How to fix the climate crisis* by Tim Lenton**

The challenge here is clearly highlighted on the book's cover, where "positive" is coloured a bright shiny yellow. After all, we know how tipping points work – a small change makes a big, sometimes defining, change to a system or state. In climate terms, that could mean, for example, that major ice sheets melt, or the Atlantic Meridional Overturning Circulation collapses. The order in which tipping points happen matters too, says Tim Lenton, who has spent years modelling them.

But Lenton is after the positives in this excellent exploration of the possible. Pressure from small groups can galvanise change, he writes. Policy at the governmental level is essential, but usually needs the leverage of such groups, disruptive innovation or economic or environmental shock, he says.

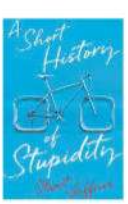
There are plenty of other factors that can come into play as forcing agents, including personal agency in the shape of individual behaviour, for example eating less meat or adopting electric vehicles.

Science popularisers may seem like a wild card, but ***Clearing the Air* by Hannah Ritchie** is a bit of a stealth weapon, since it provides data-led answers on the road to net zero. And it helps us to dismiss nonsense claims, such as that heat pumps don't work in cold weather, or questions like do wind farms kill birds. On the latter, the answer is yes, they do kill some birds, but that number is dwarfed by the annual kill rate of cats, buildings, cars and pesticides.

Nevertheless, wind turbines pose a real threat to some bats, migrating birds and birds of prey. But Ritchie points out how to reduce the risk, such as by painting turbines black, and powering down blades during low wind.

HADYNYAH/GETTY IMAGES

Lenton is also a realist, urging us to keep our eye on the bigger picture. It is very hard to imagine a time when burning fossil fuels is seen as backward or abhorrent, he writes, but that is "the nature of tipping points in social norms – what beforehand seemed impossible afterwards seems inevitable".



***A Short History of Stupidity* by Stuart Jeffries**

What could be more stupid than writing a history of stupidity, asks Stuart Jeffries, author of, er, just such a book. Luckily for him and for us, there is a lot to like in this clever exploration of a slippery subject. After all, what do we really mean by stupidity? Ignorance? Foolishness? Inability to learn? As Jeffries says, stupid is a judgement, not a fact – science can't measure it, except perhaps negatively, by measuring low IQ scores.

Jeffries's quest to understand stupidity is a historical, political and global take, so we're off on a great philosophical adventure, through Plato, Socrates, Voltaire, Schopenhauer – and multiple obscure and less obscure thinkers. Also included are various schools of Eastern thinking (Daoism, Confucianism, Buddhism and more), which take a different view from the West, in that the pursuit of intelligence may get in the way of personal development or the enlightenment Buddhists call Nirvana. All in all, there are no signs of stupidity in this delightful and unexpected book.

***What's on Her Mind?* by Allison Daminger**

Most of us will recognise this stream of consciousness running as a background to our lives: "Have the kids had enough protein this week?"; "What bedframe would look good in our bedroom?" and the like. This is "cognitive household labor", the mental labour that keeps families afloat, and sociologist Allison Daminger says it is "missing from most studies of how we do gender via housework".

It is an excellent point in a book that should receive all the positive reviews it can get. ***Breadwinners* by Melissa Hogenboom** is a similar examination, exposing the hidden power dynamics and unconscious cognitive biases shaping our lives. As our reviewer wrote, it makes a compelling, evidence-based case for recognising these imbalances and identifying where and how to correct them. Perfect family reading over the holidays.

***Unequal* by Eugenia Cheng**

You might think things are either equal or they aren't, but for mathematician Eugenia Cheng, some things are more equal than others – in maths and in life.

Her clever exploration of the meaning of "equals" helps us grasp its mathematical complexities – and the everyday dangers of assuming, for example, two people who score the same on an IQ test are equally intelligent.

***Ocean Art* by Helen Scales**

This book offers a fascinating opportunity to see art and science reflect

off each other in a richly illustrated tour of artwork about the ocean, starting at its coastlines and ending at its abysses.

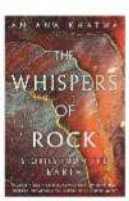
At school, the book's author, marine biologist Helen Scales, was asked to choose between following an artistic life and a scientific one. Here she indulges both, aiming to select works that "celebrate the diversity of life in the sea", and to show how artists and scientists working together have played an important part in describing and recording the biodiversity of our oceans. Drawings still play a key role, as Scales recalls a conversation with an ichthyologist, who knew he would need to use both sketching and scientific skills to achieve a true classification of an odd-looking female deep-sea anglerfish.

***The Lost Girls of Autism* by Gina Rippon**
Discovering the true state of affairs about women, girls and autism – that the prevalence of autism in this group has been underestimated – can only be good. But for neuroscientist Gina Rippon, it is also bittersweet. In this excellent, state-of-the-art account of autism in girls, she admits that by accepting the mantra that autism was much more common in boys, "I have been part of the problem I'm hoping this book will solve".

One person's story she shares makes the point. "Alice" was a woman with two young sons – one neurotypical, the elder autistic. She had mental health struggles at university, and after nearly three years of pleading for an assessment, she was finally confirmed to be on the spectrum.

Alice's path had been strewn with diagnoses, including borderline personality disorder with social anxiety. But the light-bulb moment came when she took her son, "Peter", to his first day at nursery school, anxious to see how he would settle.

Peter dived into the melee, as Alice watched, stunned. She told Rippon, "He was a native of the world I had been watching from the outside... He just seemed to automatically... belong." She realised that she was "looking at what *not* being autistic meant".



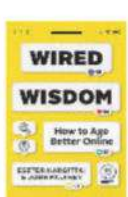
***The Whispers of Rock* by Anjana Khatwa**
Earth scientist Anjana Khatwa unites science and spirituality in a gorgeous journey through deep time, a personal view of the world of rocks and minerals. She explains how geology is at the heart of today's biggest issues, how the field itself isn't known for its diversity – and the origins of the ivory-white Makrana marble that made the Taj Mahal, among other structures.

***Tree Hunting* by Paul Wood**
What is Barney? Why do we remember the Sycamore Gap? How old is ancient? The answers lie in a truly ambitious, very fat, glorious book of trees, complete with maps, photographs and travel notes. It is built round the unusual idea of setting out in search of the 1000 best individual trees that grow in the towns and cities of Britain and Ireland.

The handsome book spun out of Paul Wood's field trip feels like an appropriately slow way to honour organisms that can live to 3000 years and that shape or are shaped by the places where they grow. Savour during the colder months, while you plan your own tree trip.

***Flower Day* by Sandra Knapp**
To understand orchids, think like a matchmaker, writes Sandra Knapp, a senior botanist at London's Natural History Museum. She is discussing the reproductive habits of *Angraecum cadetti* in this book, part of the *Earth Day* series. This is a clever conceit: take any living thing, describe one species at a given hour across 24 hours, and illustrate it (here the illustrator is Katie Scott). *Mushroom Day* and *Tree Day* are also in 2025's crop; *Shell Day* and *Snake Day* are planned for 2026.

Knapp introduces flowers from everywhere, of every hue, size and reproductive system. There is a nod to Carl Linnaeus: the European chicory's blue flowers occupy the 4am time slot, in line with his suggestion to plant them early morning.



***Wired for Wisdom* by Eszther Hargittai and John Palfrey**
"Do you need help with that?" Few words are as guaranteed to send a 60-plus adult who seems to be struggling with technology into a rage. How refreshing to find a book prepared to sift science from stereotype in what the authors call an especially "unsettled" research area of older adults and tech.

One reason for the authors to weigh in early is that even though older adults are an increasing portion of Earth's billions, they feel ignored – and subject to negative preconceptions by younger people. A healthy and inclusive society, say the authors, needs this older population on board.

Among the book's great takeaways are that older adults are less likely to fall for fake news or scams. Their use of mobile tech is also rising fast, with the number of over-60s in the US with smartphones rising from 13 per cent in 2012 to 61 per cent by 2021. With such buy-in, can we afford to indulge stereotypes?

***Seven Brief Lessons on Physics* by Carlo Rovelli**
The two friends to whom I gave copies of this book when it first came out 10 years ago hadn't heard of Carlo Rovelli, but they both ended up loving it. Now there's a special hardback anniversary issue out, to remind us that in a mere 79 pages, Rovelli's lessons managed to span the theory of general relativity, quantum mechanics, black holes, elementary particles and more.

After 10 years of polycrisis, re-reading the final chapter now seems to capture the human dilemma perfectly. An ultra-curious yet dangerous *Homo* on the brink of self-wrought destruction can still marvel at the world, because, Rovelli writes, "on the edge of what we know, in contact with the ocean of the unknown, shines the mystery and the beauty of the world. And it's breathtaking."

The ideal gift for anyone you know who hasn't read it yet, in a lovely new package.

Out of this world

From drowned worlds to virtual utopias via deep space, wild ideas abound in **Emily H. Wilson**'s picks for her favourite sci-fi reads of 2025

MIKKELWILLIAM/GETTY IMAGES

SO: WHAT were the best works of science fiction published this year? I will start with two new books that aren't actually new, but have only just been published in English.

First up is *Ice* by Jacek Dukaj, originally published to great acclaim in Poland all the way back in 2007. It is an alternative history set in Europe in the early 1920s. A terrible winter grips the land, and the cause of it may be something very alien. Our hero must set out on the Trans-Siberian Express to find out what's going on.

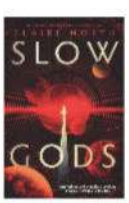
The vibe of the book is a little bit like Philip Pullman's *His Dark Materials*, if you can imagine Pullman's trilogy rewritten as a piece of early Russian literature, and also rendered dark and adult, with many of its sentences extended until they are three pages long.

I prefer my sentences short. However, if you are interested in an important and wildly inventive work of sci-fi and unafraid of a long and challenging read, this might be for you.

Second is *Beasts of the Sea* by Iida Turpeinen, a sensation when it was published in Finland in 2023. It is a novel about science rather than a work of science fiction, but it is beautifully written, and an almost ludicrously easy read compared with *Ice*. It is a story about the natural world and environmental destruction, told through the fate of the now-extinct Steller's sea cow. It would make a wonderful seasonal gift for someone who likes books (fiction or non-fiction) about sea voyages in the 1700s and the early days of scientific discovery.

Now I come to the books that have stayed with me from earlier in the year, which I would press eagerly into the hands of any sci-fi reader.

My stand-out new sci-fi of the year is *Slow Gods*, the first work of science fiction from the acclaimed author Claire North.



New sci-fi these days is often compared to the work of the late Iain M. Banks, for the simple reason that publishers know there are a lot of Banks fans out there. Normally the comparison is a stretch, but *Slow Gods* has the range and pluck to deserve it.

Sticking with books in the classic sci-fi mould, I would also recommend *Here and Beyond* by Hal LaCroix for anyone who is a sucker for a generation ark ship story, as I am.

What We Can Know by Ian McEwan is far from classic sci-fi, but it is set in the future in a drowned version of England, so it counts as speculative, environmental and dystopian fiction, I suppose, and as such lies firmly within my purview. Even if you don't think of yourself as a McEwan fan, I think this is well worth reading; so many aspects of it have stayed with me.

Another (very different) new work that can also be described as speculative, environmental and dystopian is *Briefly Very Beautiful*, a terrific debut from Roz Dineen in which the UK is now very hot.

"New sci-fi is often compared to the work of Iain M. Banks. *Slow Gods* has the range and pluck to deserve it"

If you like short stories and essays about reading, writing and sci-fi, I thoroughly recommend *A View from the Stars* by Cixin Liu, the blockbuster author of *The Three-Body Problem*. This collection of fiction and non-fiction underlines what an amazing writer and thinker Liu is.

On the future-tech front, I loved *Somebody Like Me* by Lucy Lapinska (which explores robot rights) and *Every Version of You* by Grace Chan (a fresh take on humanity diving into an all-digital future).

Finally, I read three old classics this year that more than stood up to the test of time, if you want some gift ideas for fledgling sci-fi fans: *The Prestige* by Christopher Priest (a mind-bending puzzle), *Neuromancer* by William Gibson (it launched the cyberpunk movement, but it is still entirely relevant and unbeaten) and *The Draco Tavern* by Larry Niven (interlinked short stories dripping with astounding ideas).

Happy reading to you all! ▮

Emily H. Wilson is the author of *The Sumerians* trilogy, historical fantasy novels set in Sumer. She is currently working on her first sci-fi novel

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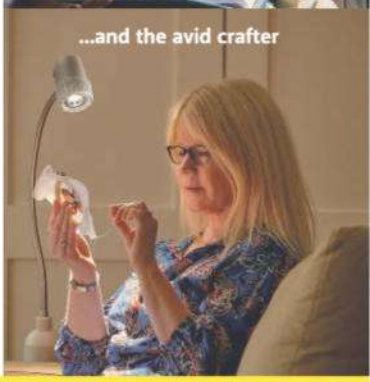

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Editor's pick

Why survival of the nicest really does make sense

15 November, p 19

From Tony Ferns, Hitchin, Hertfordshire, UK

With regard to Jonathan Goodman's article on how "survival of the nicest" makes no sense when seen in evolutionary terms, one can see the frustration in those who try to seek explanations in terms only of an individual's genes and consequent behaviour.

For most of human history we have lived in small clans or tribes. Within a tribe, close bonding of all the members and a high level of mutual trust has been necessary for the tribe to survive, and this has selected genes for the required behaviours. The real pressure to select for "altruism" has come from competition between tribes. If two similar-sized tribes came to be competing for land, prey or other resources, the tribe that worked most cooperatively would be more effective, and therefore likely to prosper.

Put simply, I don't have to survive and breed to pass on the selfish genes for altruism. It is enough if my siblings or cousins, or even more distant relatives, carrying mostly these same genes, thrive in my place.

We don't need no education, but we do need jobs

15 November, p 20

From Florence Leroy, Swindon, Wiltshire, UK

I agree with Annalee Newitz that we live in a great era, when quality education of the highest level can be accessed without physically attending an institution. However, people need jobs, as no other model of earning one's own means is really available for most of us. This implies that to be truly valuable, these courses must be recognised by employers. Without this, they may not stand the test of time.

Are we just a bunch of arrogant apes?

15 November, p 25

From Andrew Whiteley, Consett, Durham, UK

Elle Hunt gives a positive review of Christine Webb's book *The Arrogant Ape*, which aims to demolish the myth of human exceptionalism. Yet it is the case, for example, that while we hold people morally accountable for their actions, we don't do this with other animals. This suggests that human exceptionalism may not be quite the arrogant myth it is claimed to be.

Humans are indeed evolved animals and share the needs, emotions, appetites and instincts of other creatures. Morality, however, isn't an instinct. It is a way of understanding the nature of actions, by which we judge our instincts and whether we should follow them. Yes, humans are animals; problems arise only when we add the fatal words "nothing but".

From Denis Watkins, Truro, Cornwall, UK

Christine Webb offers a much-needed challenge to the "God made man in his image" view and its consequences. The myth persists in various forms despite humans continuing the wrecking of the planet and the extinction of its creatures. The *Homo sapiens* name is richly ironic for what might more accurately be described as the human pest.

From Hans Jenks, Portland, Oregon, US

If I'm not mistaken, we are the fastest, strongest, smartest, most innovative, curious, talented species on the planet. With our incredible minds, we have made supersonic jets and Mars rovers, and harnessed the power of the atom. Meanwhile, chimps are still slinging poop at each other. Show us some respect. Admiration. Awe.

How to know when it's the right time to give up

15 November, p 28

From James Stone, Buxton, Derbyshire, UK

We can learn much about when to give up from the natural world. When a bee is collecting pollen, there is an optimal time to give up expending increasing amounts of energy, and deliver the pollen to the hive.

Charnov's marginal value theorem states that if there are diminishing returns on effort (which there usually are) then maximising long-term rewards is achieved by quitting when the initially high instantaneous reward rate falls to a point where it equals the long-term reward rate.

The lesson for us is that we should quit struggling with an increasingly unrewarding project when the long-term reward starts to flat-line. This might seem obvious, but what is obvious is not always true, so it is good to have such intuitions confirmed by such a beautiful theorem.

Guerilla approaches to saving the planet

25 October, p 6

From John Tons, Adelaide, South Australia

There have been a number of articles about geoengineering as a means of averting catastrophic climate change. It isn't so much a scientific problem but a political one. All solutions require global cooperation – something that remains elusive. However, guerrilla approaches can work! For example, we know shrinking icecaps mean less radiation is reflected back. If every roof in the world were painted white, we would go a long way to compensating for the icecap loss. While we wouldn't get 100 per cent compliance, it is the sort of campaign that could capture the imagination.

Observing reality at the quantum scale

Letters, 11 November

From Ken Appleby, Ledbury, Herefordshire, UK

Robin Asby misunderstands the essential difference between quantum and classical. In a quantum equivalent of his observation that his cat is sleeping in one of a number of possible places when he gets home, the quantum "cat" is in none of the locations until he observes it (or all of them, depending on which interpretation of quantum mechanics you choose) and the actual location is chosen randomly at the point of measurement.

Swap the cat for an electron and this kind of experimental result, true randomness at the point of measurement, is readily observed. At the quantum scale, reality is just different. There really is a divide between "the world of the very small" and "our everyday world".

A simple solution to consciousness

25 October, p 36

From John Healey, Adelaide, South Australia

With regard to our inability to analyse consciousness, may I offer the following Gödelian observation? If our minds were simple enough to understand, we would be too simple to understand them. ▮

For the record

▮ **The answer to the second part of BrainTwister #97 is 67**

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Pangolin population collapsing. Help launch crisis clinic.

Fauna & Flora
Saving Nature Together

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The pangolin is the most trafficked mammal on the planet. By some estimates, up to 2.7 million pangolins are taken from the wild in Africa alone every year.

You can give rescued pangolins the life-saving treatment they need today.

- **The illegal pangolin trade is reaching critical levels, sending populations plummeting towards extinction.**
- **Pangolins rescued from the illegal wildlife trade are often weak, starving and dangerously stressed.**
- **Funds are sought immediately to launch a Pangolin Crisis Clinic, to rehabilitate and release rescued pangolins.**
- **Without this clinic, pangolins rescued from poachers are almost certain to succumb to their injuries.**

©Elliott Spencer

"Please help save the humble pangolin. By donating to Fauna & Flora, you can protect these precious creatures."

- Sir Stephen Fry, Fauna & Flora supporter since 2009.

Pangolins have waddled the Earth for over 55 million years, but their time could soon run out.

They've endured by living carefully – curling into a tight, armoured ball whenever danger approached. That simple defence saw them through the era of sabre-toothed cats, giant crocodilians, and even half-ton prehistoric lions.

But today, against poachers, it offers no protection. Not from snares. Not from sacks. Not from freshly sharpened machetes. **Pangolins are easily picked up and smuggled overseas to satisfy the sickening illegal wildlife trade.**

Their scales – made of nothing more than keratin, the same substance as our fingernails – are ground into powders to make potions and poultices, claimed to possess healing powers.

Their blood is drunk to increase male virility, and even their foetuses are eaten in soups for similar reasons.

Not one of these claims has a shred of scientific credibility.

It's causing a massacre of staggering proportion. By some estimates, up to 2.7 million pangolins are taken from the wild in Africa alone every year – that's 7,400 a day. **More than five every single minute.**

No mammal on Earth is trafficked more heavily. **If we don't act now, pangolins could face the very real prospect of extinction.**

With trafficking networks sprawling across the continent, the most effective way to stop them is not to scatter protection efforts thinly – but to strike with precision and target trafficking hotspots.

Mozambique is a known hotspot for pangolin trafficking and a crossroads for international trade – especially between southern Africa, China and Vietnam.

World-leading conservation charity Fauna & Flora has **created a plan to help stop the trade in this region and save the pangolins** that are rescued from poachers.

But the team is still £78,736 short of what's needed to launch this critical mission.

The charity urgently needs your support today to set up a vital pangolin crisis clinic at the heart of the mission headquarters.

Trafficked pangolins are often kept alive in horrific conditions until sold, so sellers can display them to customers, proving the blood

© Alfredo Gotine / Fauna & Flora

With so few left, every pangolin matters. That's why we urgently need to rescue and rehabilitate injured pangolins.

£30
could supply life-saving antibiotics for a pangolin fighting infection from snare wounds.

£980
could equip the clinic with an indispensible health monitor to track vital signs like heart rate, blood pressure and oxygen levels.

£68
could provide surgical tools to repair broken limbs and other critical injuries.

£10
could provide sugar serum to help stabilise rescued pangolins suffering from shock.

For illlustrative purposes only

You'll be creating the first dedicated facility of its kind in the region, providing emergency stabilisation across more than 100 km of pangolin trafficking red zone. The aim of this groundbreaking clinic is to rescue, rehabilitate and re-release as many pangolins as possible back into the wild - all thanks to your donations.

or body parts they're offering are "genuine."

By the time they're rescued, many are in critical condition – severely stressed, dangerously dehydrated, and often suffering from septic or hypovolemic shock. **Without immediate specialist care, many don't survive.**

That's why your donation today would be life-saving.

You'd be helping to launch a facility where rescued pangolins can be rapidly stabilised and rehabilitated. Your support will provide equipment such as **basic medicines, fluids, bandages and gloves.**

For more critical cases, you'll be helping to provide an x-ray machine which can find fractures in pangolins who've been battered around like cargo in transit, and **surgical equipment to repair torn limbs and deep gashes inflicted by traffickers.**

Fauna & Flora is completely reliant on readers like you to launch this critical mission. Without these things, even the best rangers in the world won't be able to save them.

But with you, those pangolins can live, and their species has a chance at holding on.

Fauna & Flora is the world's oldest international conservation organisation, trusted worldwide by scientists, conservation experts and global leaders, including Vice-President Sir David Attenborough and Patron Prince William. The charity focuses their expenditure on delivering real, impactful outcomes over excess publicity, which is why many people have never heard of them. **To donate, please call 01223 749019, visit www.fauna-flora.org/pangolin to donate online, or return the cut-out coupon below. Thank you.**

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Fixing quantum theory's fatal flaw

A new take on quantum cause and effect could bridge the gap between quantum theory and our experience of reality, says physicist **Ciarán Gilligan-Lee**

THE ball rolls across the floor because it was kicked, just as Earth orbits the sun because it is tugged by gravity. The connection between cause and effect is fundamental to how we understand the world – or at least, it is for the world we see, governed by classical physics.

Notoriously, everything gets murkier in the underlying realm of atoms and subatomic particles described by quantum theory. But, as a fundamental physicist who develops algorithms to extract cause and effect from correlations, I have long believed that causality could help us solve the mystery at the heart of quantum mechanics: the confounding notion that quantum systems like electrons exist in a state of uncertainty until an observer measures them.

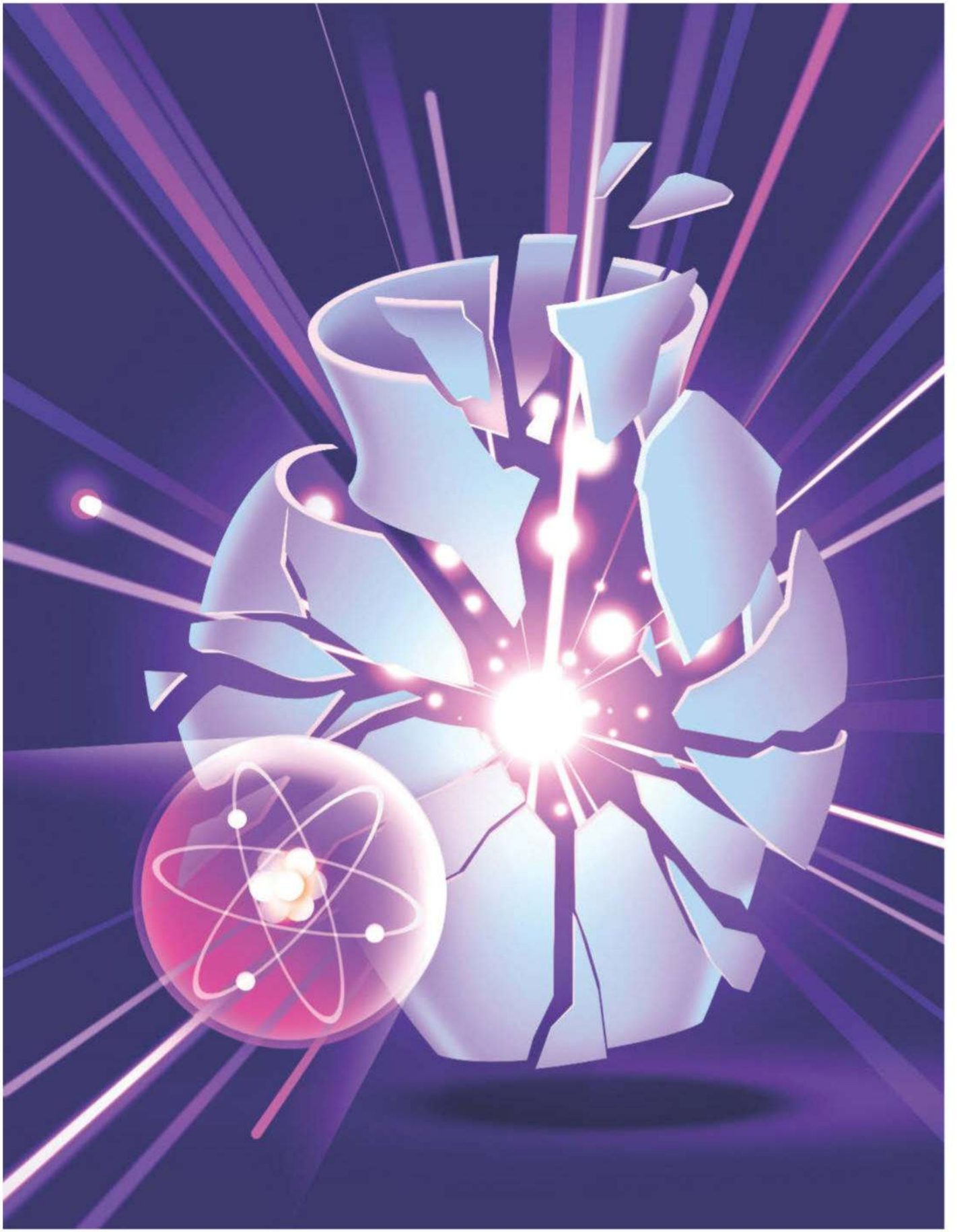
This is why I am intrigued by a fresh attempt to rid quantum theory of this so-called observer problem. Building on insights from existing interpretations and recently developed models of quantum causality, this new take uses the precise mathematics of cause and effect to show how interactions between and within quantum systems can determine which of the many possible ways they could change over time actually happen, without any reference to the mysterious power of observers.

What it amounts to is a quietly radical rethink of reality. In this view, quantum causality is the most essential aspect of reality from which the cosmos springs. Remarkably, this view seems to resolve several quantum paradoxes in one fell swoop. Perhaps the biggest indication that it might be on the right track is that it could also provide a plausible route to the long-sought holy grail of physics: a theory that unifies quantum theory with Albert Einstein's theory of general relativity.

Quantum mechanics is, without doubt, one of our most successful scientific theories. It describes the often counterintuitive behaviour of subatomic particles with incredible accuracy, precisely predicting the outcomes of countless experiments. It is also the source of endless confusion, however, because ever since it was first devised, it has resisted attempts to make sense of what it means for our understanding of reality.

Our frustrations boil down to the vagueness of the concept of "measurement" at the heart of the theory. Until we measure a particle, its properties are best described by the Schrödinger equation and its famous "wave function", which paints those properties as a kind of fog of possible alternatives. This allows us to calculate the odds on which of them we will see when a particle is measured. But it can't tell us the outcome of any measurement. Until we make one, all we have is probabilities.

The upshot is that the observer who performs the measurement is all-important. ›



ADRIÀ VOLTÀ

The gnawing problem is that it isn't at all clear what qualifies as an observer. With no precise definition, quantum theory offers no answer to the key question of how and why the world we see – where particles have definite properties – emerges from the quantum fog.

That's why many physicists view quantum theory as it is typically understood to be deeply unsatisfying. "The current situation with quantum mechanics is that it's a theory that predicts very well and explains very badly," says Nick Ormrod at the Perimeter Institute for Theoretical Physics in Waterloo, Canada. We can't just fall back on the phrase "because we measure it", he says, particularly as many suspect that the vagueness of quantum theory is a big part of why physicists struggle to apply it in contexts where no observers are present, such as the very early universe or the fabric of space-time.

Observer-free space

What we require, then, is an interpretation that removes the need for observers. In fact, we already have several on the table (see "The meaning of quantum theory", right). And while they are imperfect, Ormrod and his colleague Jonathan Barrett at the University of Oxford wondered if two of them might be refined to build a more coherent, observer-independent take on quantum theory.

The first of those proposals is known as the consistent histories interpretation, which was developed in the 1980s. Rather than treating measurement as a special process, it instead focuses on all the ways a quantum system could feasibly evolve over time – in other words, what happens between measurements. It identifies sequences of properties that the system (that is, a set of particles, for example) could have at different times, known as "histories", and assigns probabilities to them, so long as they are internally consistent, meaning they can be calculated according to the standard rules of logic and classical probability. Crucially, and somewhat surprisingly, it turns out that all quantum phenomena can be modelled this way: there is no need for measurement or observers.

In this view, the act of measurement is just one way of accessing a history, seemingly removing its mysterious power to select an outcome from quantum uncertainty. But there is a catch: there isn't just one consistent history a quantum system could follow, but many. The framework doesn't contain anything that tells

The meaning of quantum theory

The deepest problem with quantum theory is that it describes a reality in which nothing ever seems to be fixed before we measure it, even though reality as we experience it is composed of objects with definite properties. How and why the latter arises from the former is known as the measurement problem, and while causality may provide an exciting new solution (see main story), it isn't the only one available.

One alternative is the *Copenhagen interpretation*, which simply says that quantum theory doesn't give us any information about what particles are doing before we measure them. It amounts to saying that physicists shouldn't worry about the metaphysical meaning of quantum theory – which is why physicist David Mermin once called it the "shut up and calculate" approach.

If that sounds conservative, the *many-worlds interpretation* is at the other end of the spectrum. This idea, first formulated by physicist Hugh Everett in the late 1950s, says that all possible outcomes of a measurement are realised – just in other universes. The implication that reality is constantly branching is, for some, so strange that it is difficult to swallow.

For a long time, physicists suspected that quantum theory appeared so strange only because it was incomplete. *Hidden-variable theories*, which come in many flavours, say there is some piece of the puzzle we are missing that would explain how and why we get the outcomes we do. However, many of these hypotheses have been ruled out by experiments.

A more recent – and starkly different – approach is *quantum Bayesianism*, also known as QBism. This insists that quantum theory isn't about reality in an objective sense, but only our subjective knowledge of it. When we make a measurement, we update our knowledge of a quantum particle, say, so it makes total sense that it is so hazily defined before we look. The drawback of this framework, for some, is that it abandons any hope of being able to describe the quantum world before we look at it.

Our experience of reality can't easily be explained by quantum theory

MICHAL CIZEK/AFP/GETTY IMAGES

us which represents the properties the system really had at any given time, which means it doesn't explain why we get the world we see. "You have to just sort of choose the right one and that choice feels a bit ad hoc," says Ormrod.

The second interpretation, known as relational quantum mechanics, developed in the 1990s, is simpler to state: the properties of a quantum system exist only at the point of its interaction with another such system. This means that any physical system can act as an observer and, more importantly, that reality isn't absolute, but is relative to the observer – whether people or particles. Think, for example, of a sunset: it only makes sense to talk about a sunset if we acknowledge it as something observed by a particular person in a certain position on Earth's surface. In that sense, a sunset is relative. In the relational interpretation of quantum mechanics, every aspect of reality must be seen in a similar light.

The problem with this view, according to Ormrod, is that it lacks the sort of precisely defined mathematical framework required to properly scrutinise it. I agree with him. There is currently no formalism that provides a clear-cut definition of ambiguous notions such as "interaction" and "relative". As such, it isn't obvious exactly what relational quantum mechanics tells us about reality, or how it might change the way we approach efforts to construct a coherent theory of quantum gravity.

SIBYLLE PIETREK/PLAIN PICTURE

In our reality, one thing always leads to another

Quantum causality

Which is where cause and effect comes in. Now, you might think it seems odd to apply classical notions of how things influence each other to the quantum world, which doesn't play by the same rules. But to me, and to some other physicists, it has always made sense given that causal reasoning possesses extraordinary explanatory power. "You can't do physics without using cause and effect," says Robin Lorenz, a researcher in causality and quantum computing at Quantinuum. "Causality is the bread and butter of the sciences." What's more – and this is vital – these days, we have a better understanding of how cause and effect operate in the quantum regime.

What Ormrod and Barrett realised is that we can marry the tantalising insights from the consistent histories interpretation and relational quantum mechanics, then overcome their flaws by underpinning them with recently developed models of quantum causality – and by elevating those causal structures to fundamental status.

In a paper released in 2024, they showed that if we consider quantum systems as a network of "causal bubbles" with specific mathematical rules for how subsystems within a bubble influence one another, the "correct" sequence of properties a given bubble has or had over time naturally emerges. In other words, the causal structure of the system determines how it evolves – that is, what properties it has at any given moment – in a way that matches what we would predict with standard quantum theory, but without needing to appeal to the mysterious powers of external observers. "By analysing a quantum causal structure, you can always derive a unique set of consistent histories," says Ormrod.

Truly grasping the appeal of this model requires some advanced mathematical skills. To get a sense of what it amounts to, however, Ormrod suggests thinking of a spider's web. The spider doesn't begin with a set of points and connect them with threads. Rather, it begins with the threads, laying them down one after another – and where they interact, points form.

> "Quantum mechanics is a theory that predicts very well and explains very badly"

The key thing is that points in the spider's web aren't fundamental. They are by-products of how the threads are woven. "The points only exist because of the pieces of thread," says Ormrod. "They emerge from the threads. The threads are actually the conceptually fundamental thing."

In the same way, Ormrod and Barrett suggest, causation is the fundamental "thread" from which quantum reality emerges. The properties of particles are the points, the places where causal influences interact. But the causal structure – the threads – comes first. The properties of a quantum system – what we might call reality – emerge from causality, rather than from the mysterious and ill-defined process of measurement.

In any case, there are already reasons to think they are onto something with this new interpretation, which is sufficiently novel that it doesn't yet have a name. One is that it can resolve a troubling conundrum that has, in recent years, brought the observer problem into sharper focus. First devised as a thought experiment and later recreated with particles in the lab, the Wigner's friend paradox demonstrates that two observers – Wigner observing his friend making measurements ›

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on a quantum system in a lab from the outside – can have two contradictory experiences of reality. The implication is that quantum theory insists there is no such thing as objective, observer-independent reality, and renders the standard interpretation extremely problematic.

In Ormrod and Barrett's framework, the Wigner's friend paradox dissolves. The key is that the notion of a "definite outcome" is tied to causal structure, not to observation. Inside the lab, the friend is embedded in one causal bubble: the particle influences the apparatus, which influences their sensory experience. Within that causal bubble, the outcome is definite. From outside, however, Wigner is in a different causal bubble. What we learn from Ormrod and Barrett's take on quantum theory is that, in this scenario, the friend's measurement exerts a quantum influence on Wigner's outcome, which precludes it from being part of the consistent history in his causal bubble. Relative to the bubble that includes Wigner's outcome, the friend doesn't obtain any measurement outcome at all.

In other words, both perspectives are correct, but are relative to their causal bubbles. There is no contradiction, because "definiteness" isn't an absolute fact about the world, but a relational fact about causal structures. By making causation, not observation, the foundation, the framework elegantly sidesteps the need to favour one viewpoint. Realising that their framework resolved this paradox "was an amazing moment", says Ormrod.

Underpinning space-time

The other reason to take this new interpretation seriously has to do with the possibility of applying it to fundamental questions about the universe. The thing is, the notion that causality might be more fundamental than the entities it relates to also plays a role in our understanding of general relativity, which casts gravity as the result of mass warping space-time. There is a classic discovery from the 1970s that shows that if you know the causal structure of space-time – roughly, which points can influence which others – you can reconstruct its geometry, distances and even the flow of time. "Causation is playing a very important role in shaping space-time structure," says Ormrod.

This means space–time itself may be thought of as emerging from causal order. With that in mind, physicists seeking to reconcile quantum theory and general relativity to form a quantum theory of gravity have long speculated that the universe's deepest layer may be a causal network, from which both geometry and matter emerge. If this is correct, Ormrod and Barrett's interpretation is even more striking. On the quantum side, they show how the properties of a quantum system emerge naturally from causal structure. On the relativity side, causal structure already underpins space-time geometry. Taken together, the suggestion is tantalising: what if causality is the common root of both pillars of modern physics, and a foundation on which to unify them?

GIROSCIENCE/SCIENCE PHOTO LIBRARY

Are quantum systems made up of a network of causal bubbles?

Other attempts to unite quantum mechanics and relativity have taken very different routes. String theory, for example, imagines the fundamental building blocks as vibrating strings in higher dimensions. It is a bold idea that has inspired decades of research, but it has yet to deliver a complete, testable theory. What makes the causal approach appealing is its simplicity. Instead of inventing exotic new entities, it asks whether the familiar idea of cause and effect could be the missing foundation. If space-time and the properties of quantum systems both emerge from causality, then perhaps cooking up a viable theory of quantum gravity is less about discovering new ingredients and more about rearranging the ingredients we already have. "It seems highly suggestive that we've got these two similar emergence stories in the two theories that we're attempting to unify," says Ormrod.

> "You can't do physics without using cause and effect. Causality is the bread and butter of the sciences"

For now, this is just informed speculation. But what we have with Ormrod and Barrett's new interpretation is the outline of a framework that offers a bold answer to quantum theory's greatest mystery: not just how the theory predicts outcomes, but why those outcomes occur. To me, that alone is remarkable. Because if we take seriously the idea that causality, rather than observation, is the foundation of reality, the bedrock from which the world we see emerges, we may finally be closer to understanding the quantum realm on its own terms. ▮

Ciarán Gilligan-Lee leads a research team teaching machines cause and effect at Spotify

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Heroes in disguise

The long-overlooked hoverfly could help offset the decline of bees and save our crops, discovers **Marta Zaraska**

DARA OJO

It takes Mandela Fernández-Grandon 15 minutes to train a hoverfly, a harmless wasp look-alike. The entomologist at the University of Greenwich, UK, immobilises each tiny insect in a cocoon-like holder, then releases a flowery scent near its antennae. Next comes a sugary reward, which makes the hoverfly extend its proboscis – a long, tube-like mouthpart used to drink nectar.

After a couple of trials, the hoverfly reacts the moment it detects the aroma, like Pavlov's dogs at the sound of a bell. And the hungrier it is, the faster it learns. Fernández-Grandon thinks such training could make hoverflies better pollinators, with benefits for agriculture.

In fact, these long-overlooked creatures could help offset the collapse of bees, which has been widely reported in recent years and often obscures the importance of other pollinators. "They are not as cute as bees," admits Fernández-Grandon. "They just don't have the same publicity." But now that we are gaining a better understanding of these incredible insects, that could be changing.

Even without training, hoverflies pollinate almost three-quarters of global food crop species, a service worth $300 billion per year. And they have several advantages over bees. "In some ways, they're potentially more useful," says entomologist Will Hawkes at the University of Exeter, UK. For a start, they aren't deterred by bad weather and, unlike bees, they migrate thousands of miles, dispersing pollen over vast distances. What's more, their larvae decompose dead matter and devour pests.

"Isn't it fantastic that you can have something that, in its juvenile stage, is providing pest-control service and reducing our reliance on synthetic pesticides, and then they grow up and become pollinators?" says Fernández-Grandon.

Many hoverfly species resemble wasps or bees, but they aren't actually closely related to them. Hoverflies, which probably evolved their deceptive appearance to protect against predators, can be recognised by their stillness in midair, compared with wasps' purposeful darting. These tiny drones are an engineer's dream: they can accelerate quickly, change direction in a mere six wing-beats and fly at speeds in excess of 35 kilometres an hour. This is impressive considering their size, as larger animals generally fly faster.

Worldwide, there are about 6000 hoverfly species, some living on mountaintops 4000 metres above sea level, others in the Arctic. The UK alone is home to 279 species – 19 more than bees. These include the marmalade hoverfly, which resembles a tiny wasp and can be spotted in suburban gardens, often hanging out over sunlit daisies and dandelions. The narcissus bulb fly is more similar to the bumblebee, as it is rounder and quite hairy. And the long hoverfly, as its name suggests, is slender, resembling a wasp that has been stretched into a flying stick.

> "What hoverflies lack in hairiness compared with bees, they make up for in motivation"

Just like honeybees and their larvae, adult hoverflies feed on pollen and nectar. But hoverfly larvae have different tastes. They can be found on dead wood, rotting plants or dung, feeding and helping to decompose organic matter. Some even filter bacteria and fungi from freshwater – and have the potential to be used to clean up sewage.

Then there are the predatory hoverfly larvae that farmers can buy as a form of natural pest control. Lab experiments show that hoverfly larvae can feed fast enough to suppress populations of pests in various crops, from wheat to apples. A single marmalade hoverfly larva can devour as many as 400 cereal-infesting aphids during its development. *Eupeodes corollae*, the species Fernández-Grandon trains, can kill off 62 per cent of aphids on strawberries. On melons, that rate can be close to 100 per cent.

When it comes to pollination, honeybees may look slightly better on paper: they pollinate 80 per cent of flowering plant species. Hoverflies, meanwhile, do so for about 70 per cent of the wildflowers that depend on animals for pollination and 72 per cent of all food crops. A single hoverfly also tends to be a less efficient pollinator than a honeybee.

One key factor is hairiness: insects that are hairier, especially on their faces, can carry more pollen than less-fuzzy species, which includes most hoverflies. A furry ball of a bumblebee, for example, can carry 15,000 grains of pollen on its body. That's around four times as many as a common drone fly, a type of hoverfly that looks like a male bee and is found on every continent except Antarctica.

However, overall, a hoverfly pulls a similar workload to a bee, says Axel Ssymank, an entomologist at the German Federal Agency for Nature Conservation. What they lack in hairiness, they make up for in motivation. They visit more flowers within a field and don't mind working in poor conditions.

A recent study conducted in a Japanese pear orchard found that honeybees showed up to pollinate only when it was warm, whereas hoverflies worked regardless of the weather. As a result, hoverflies prove to be great farm workers. Research shows they can be as effective as bees at pollinating a variety of crops, including onions, bok choy, watermelon and caraway, and may even outperform bees on others, such as carrots and strawberries.

Besides, pollination isn't a zero-sum game. "A flower is able to be pollinated by both bees and hoverflies. They're sort of complementing each other," says Ssymank. In fact, a plant is much better off if it is visited by both types ›

of insect, because this ensures that pollination is more complete.

"It's not only the amount of seed production, but also, for example, the quality of fruits that is better," he says. Take avocados in Australia. Most producers there use managed honeybees to pollinate the crop, but a study earlier this year showed that on fields where common drone flies were released as well, avocado yields almost doubled.

What's more, hoverflies do something else that bees just can't: they migrate. They do this "to have more sex", says Hawkes. In the UK, for example, the climate is ideal for hoverfly reproduction during the summer – but "it's terrible in the winter", he says, so the insects look for more favourable environments. While doing so, they export up to 19 billion pollen grains out of the UK, carrying these to southern Europe and Africa. Then, on their return, they bring up to 8 billion grains into the country. In a study published in September, a team of researchers observed hoverflies that had landed on a barren oil rig in the North Sea, around 200 kilometres off the coast of Scotland. On average, a single hoverfly carried pollen from eight different plant species.

Migrating hoverflies can travel hundreds of kilometres in a single day and their mass movement can be awe-inspiring. In 2017, Hawkes witnessed this for himself as a huge wave of insects came across Col de Bretolet in the Alps. Hawkes had been camping for three months in a mountain hut with no running water or electricity, waiting to witness an insect migration. At around 2pm, there came the buzzing: millions of insects all moving southwards, sweeping right above the grass. "The air was full of glistening yellow and orange hoverflies," he says.

> "During migration, hoverflies export up to 19 billion pollen grains out of the UK"

When Hawkes later analysed similar swarms in the Pyrenees, which he says resembled "a living carpet", he discovered that 90 per cent of the insects were flies, with hoverflies being the most abundant kind.

There are now 20 radar systems tracking insects on the move across Europe, from the UK and France to Finland and Latvia. Employing data from such systems, scientists have calculated that each year, up to 4 billion hoverflies migrate over southern England, heading north in the spring and south in the autumn. In terms of sheer mass, that's over seven times more than all the birds journeying over the country.

Such long-distance pollination is vital for plants: it can link geographically isolated populations, boost the genetic variety of crops and even help plants adapt to climate change by spreading genes favourable for defending against disease or drought resistance. "These animals are having a real impact on fighting the climate crisis," says Hawkes.

Extinction risks

All this leaves no doubt that hoverflies are invaluable pollinators. Unfortunately, like many insects, including bees, their numbers are falling. "We have signs that both hoverflies and bees are heavily declining," says Ssymank.

For instance, a study using data from 1980 to 2013 in the UK found an average decline of 25 per cent among various bee species, and a 24 per cent drop among hoverflies. In Germany, the numbers are even more troubling: there has been an 80 per cent decrease in hoverfly numbers over the past four decades. And in the Netherlands, the current extinction rate is one species per year – approximately two and a half times faster than the decline in bees. The European Red List of Hoverflies, a report by the International Union for Conservation of Nature that Ssymank worked on, found that of almost 900 European hoverfly species, more than a third are facing extinction.

Some of the things that threaten hoverflies are the same as those that threaten bees: pollution, pesticides, intensive agriculture and livestock farming. But there are twists in the tale. For one, managed honeybees can themselves spell trouble for hoverflies. "The public has this broad perception that the presence of bees is good, and that's led to the introduction of colonies where they shouldn't be," says Fernández-Grandon.

Studies show, for example, that poorly placed, high-density commercial beehives can spread diseases to wild pollinators – and also outcompete them. When more than 2000 beehives were placed in Teide National Park in Tenerife, the honeybees almost

HEATHER ANGEL/NATUREPL.COM

The marmalade hoverfly resembles a tiny wasp

DR G. MANDELA FERNÁNDEZ-GRANDON

NEIL PHILLIPS/ALAMY

Hoverflies can be trained to respond to flower scents (above), and their larvae devour pests on many crops, including apples

completely drained the nectar from local flowers, leaving little for wild pollinators such as hoverflies to eat. The result was a decline in the park's biodiversity.

The second specific challenge for hoverflies is the degradation of habitats for their larvae. Honeybee larvae simply need a hive and flowers to feast on, but hoverflies require a range of environments, from stagnant ponds to compost heaps and rotting wood, as the larvae of many species feed on decaying organic matter. "If you destroy these, you lose the whole hoverfly population," says Ssymank.

This is why honeybees can thrive in urban environments, whereas hoverflies don't. When scientists looked at gardens in and around Malmö, Sweden, for example, they saw that wild bees were doing fine in the inner city, but hoverflies were struggling. Likewise, on 20 "green roofs" planted with vegetation in Antwerp, Belgium, researchers counted almost 600 wild bees from 40 different species, but only 11 individual hoverflies.

Fortunately, there are solutions to stem the hoverfly decline. One can be found outside Almería, Spain. Since July this year, a start-up there called Polyfly has operated the world's first industrial plant designed to mass-rear the insects. It doesn't smell of flowers: the larvae's food stinks, says Marc Vaez-Olivera, a co-founder of Polyfly, admitting that bad odours are an occupational hazard. Nevertheless, this 5500-square-metre facility is capable of churning out a billion pollinators per year. Refrigerated, the metabolism of the hoverfly pupae slows down, putting them in a sort of suspended animation, and then they can be shipped almost anywhere in the world to be released on crops.

That's less bizarre than it sounds: after all, renting out commercial honeybee colonies for pollination is already a common practice. In the US, such services are worth about $300 million per year, and hives get hauled back and forth across the country on trucks. In a single year, hundreds of thousands of such bee colonies are brought to California to pollinate crops such as almonds, apples and blueberries.

The hoverfly-breeding business is still in its early stages, but there are many challenges: the eggs often don't hatch and the pollen used to feed reproducing adults is expensive and hard to obtain. Vaez-Olivera says he is optimistic that commercial hoverfly breeding can offer growers a "viable and environmentally sound way to enhance crop yields".

> "Hoverfly larvae need a range of environments, from stagnant ponds to rotting wood"

However, if we want to prevent these pollinators' decline in the wild, we must also protect their habitats, for example by encouraging farmers to grow wildflowers on their fields or plant trees nearby. According to a study in Canada published earlier this year, this can lead to 33 times more hoverflies on crops, compared with fields that are surrounded only by grasses.

Older trees, with hollows and deadwood left rotting on the ground, are all the better to feed hoverfly larvae. Likewise, there are big potential benefits from restoring ponds and small streams – features that have been removed from the countryside all too often through drainage and dredging.

If you have a garden, you too can help protect larval microhabitats. This can be as simple as placing an old, decaying log among your flowers. You may also want to figure out which hoverflies live in your area and find wildflower mixes that work well for them, says Fernández-Grandon. iNaturalist has a website to assist with this. Most hoverflies, for example, enjoy umbrella-shaped members of the parsley family, such as dill, cow and Queen Anne's lace.

As Fernández-Grandon trains his hoverflies, he still grapples with the question of how long the insects can remember the lessons taught in the lab. If they can recall a scent long term, that would open up the prospect of training hoverflies from commercial breeding plants to be efficient pollinators of specific crops, like strawberries or melons.

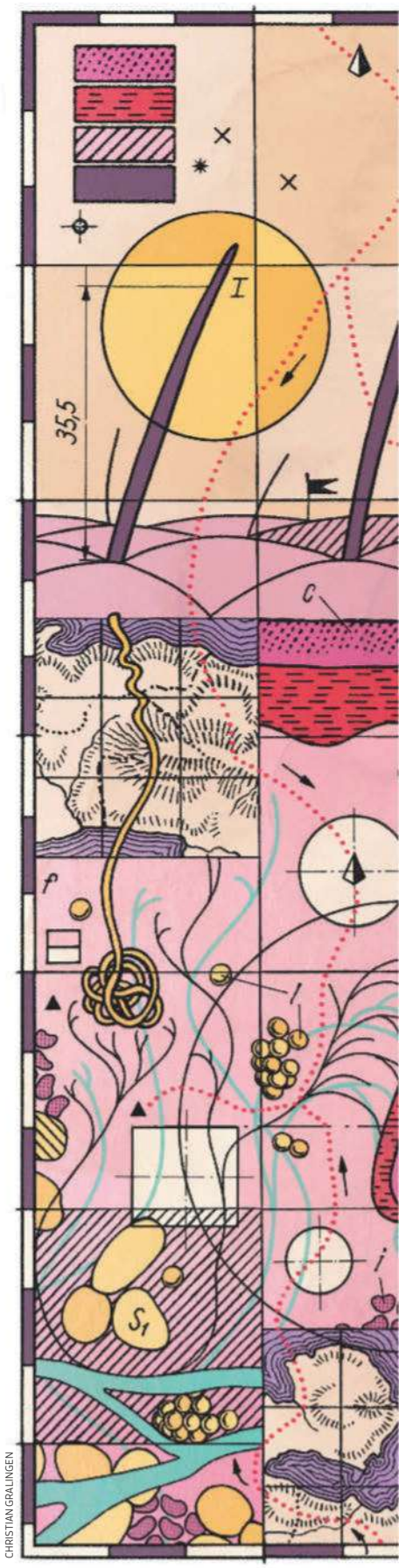
Similar training has been done with bees for almost a century. "If they had already learned what they should be looking for, then that could make quite a large difference," says Fernández-Grandon.

With bee colonies collapsing, we need all the help we can get to have our crops pollinated effectively. Drone-like hoverflies certainly have what it takes, but with their microhabitats disappearing, it's a race against time, says Hawkes. However, the fact that people are starting to pay attention to hoverflies, not just bees, gives him hope. "It's good to not put all your eggs in one basket," he says. Fernández-Grandon agrees. "We've put a bit too much focus on bees." ▮

Marta Zaraska is a science writer based in Vexin, France

Uncharted territory

A revolutionary new way of mapping disease in intricate detail is leading to treatments for deadly conditions, finds **Michael Marshall**



CHRISTIAN GRALINGEN

THIERRY NORDMANN was on his first night shift as a dermatologist at University Hospital Basel, Switzerland, when he got the emergency call. A patient was being brought in who'd had a severe reaction to their medication, which had destroyed the entire outer layer of their skin. Nordmann's job was to confirm the diagnosis with a biopsy, but it was already clear: they had lost their skin's protective barrier, leaving them wide open to infection and dehydration.

"That's a very bad combination," he says.

The medical staff sprang into action, isolating the patient to reduce their risk of infection and giving them antibodies in a bid to halt the immune cascade that was killing their skin cells.

But it didn't work. The patient died – as do about a third of people with this painful condition. "The reason was because nobody really understood what was going on," says Nordmann. "Everybody treats it differently."

The experience left him with questions. Why do some people have this intense, lethal reaction to ordinary medicines, while others don't? What exactly is happening in the cells of their skin?

Finding answers led Nordmann to a suite of emerging technologies that can study human tissue in astonishing detail, pinpointing diseased cells lying in the three-dimensional structure of our organs.

These technologies, known as spatial multiomics, are revealing what has gone wrong in the molecular machinery of those cells, and they led Nordmann to develop a new way to address a previously incurable, life-threatening condition. They could also lead to a raft of new treatments for other illnesses, including cancers, and usher in a new age of precision medicine.

Modern medicine has spent two centuries zooming in, trying to understand why our bodies sometimes go so badly wrong. We have learned to trace diseases to organs like the heart and lungs, which are made up of tissues, which are made up of cells, which are built using a host of biological molecules like DNA, RNA and proteins.

Each level matters in truly understanding a given condition. Take a cardiac arrest: the heart stops beating, which seems simple enough, but unpacking why it happens means looking at blood pressure, electrical conduction within the heart and many other other processes.

For Nordmann, the mystery was skin – and what causes it to suddenly, catastrophically, come off.

The condition Nordmann's patient had is called toxic epidermal necrolysis (TEN). While it is rare, it is also brutal and can begin after taking everyday drugs like certain antibiotics or anti-epilepsy medications. For reasons no one fully understands, the immune system reacts violently. The skin becomes red, blistered and intensely painful. "Just by movement of your thumb on this redness, you can just peel away the skin," says

Nordmann. "Within 48 hours, maybe a bit longer, these patients just shed their skin."

The effects are life-threatening. Even if people survive, they are often left with chronic complications.

"But what I've been seeing the most in these patients is fear," says Nordmann. "These patients are scared of every single drug they take." There is no obvious pattern in the treatments observed to cause TEN. And while some populations are at a substantially elevated risk, including Asian and Black people, "it can happen to almost anybody", says Nordmann.

He suspected that the path to a viable treatment, if one existed, lay deep inside the skin. But here he found he was up against a problem that has bedevilled medical researchers for decades: even within a single organ or tissue, not all cells are alike. Two neighbouring cells can behave differently, producing a different mix of proteins and chemical signals.

When cells go rogue

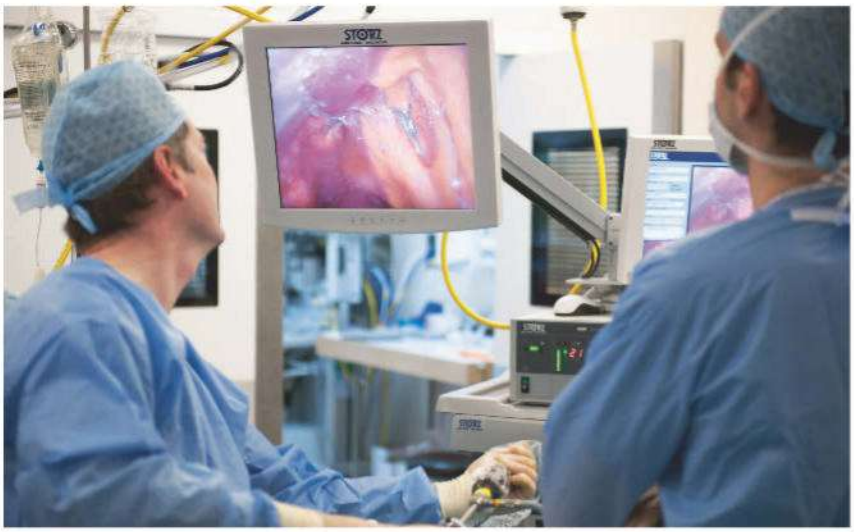
Cancer researchers have known this for years. They talk about the "tumour microenvironment" – the idea that a tumour isn't uniform, even under a microscope. "What's going on at the invasive margin or leading edge of the cancer can be different than what's going on in the central portion of the tumour," says Frank Sinicrope, an oncology professor at the Mayo Clinic in Rochester, Minnesota.

But standard lab tools struggle to resolve these cell-to-cell differences. Analyses that sample the proteins or RNA in a tissue will generally mash together hundreds of cells in order to get a large enough sample. The result is a bit like a smoothie, which researchers can use to study thousands of molecules.

Yet the crucial changes are hidden in the mush. The signal is there, but scientists can't say where it is happening.

There is another way to study diseased cells: look at them one by one. That became possible in the 2010s, when researchers learned to isolate single cells and sequence their entire genome. "We could identify that there were cell populations that we hadn't understood before," says J. Michelle Kahlenberg, a professor of rheumatic diseases at the University of Michigan in Ann Arbor.

But there was a catch. Such methods strip the cells from their context. Once removed from their tissue, it was impossible to say where each one had come from or how it ›



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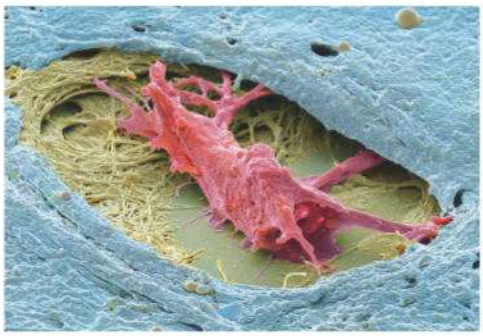

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Left: Surgeons perform laparoscopic surgery on a woman with ovarian cancer
Above: Spatial multiomics is helping scientists better treat ovarian tumours like the one shown here

"You get an entirely new picture of molecular information within a tissue"

might have affected its neighbours, and thus how abnormal behaviour spreads.

Now, though, a new generation of tools is bringing that context back.

Known collectively as spatial multiomics, these techniques build up a three-dimensional map of a tissue or organ. This helps researchers identify diseased or abnormal cells and profile them on a molecular level.

"We're on the precipice of really understanding biology in a way that will revolutionise our ability to safely treat all sorts of life-threatening illnesses," says Kahlenberg.

The term multiomics refers to the practice of studying multiple biological systems at once: genes (via genomics), RNA (via transcriptomics), proteins (via proteomics) and more. Each offers a different lens on how cells function.

Spatial multiomics adds high-resolution imaging to molecular analysis, allowing scientists to build detailed maps of living systems – not just what molecules are present, but where they are and how they interact.

Inside the tissue atlas

Andreas Mund, a researcher at the University of Copenhagen, Denmark, who helped develop the method Nordmann would later use to unpick TEN, calls it deep visual proteomics. Mund's team described its technique in 2022, and it unfolds in four stages.

It starts with a biopsy: a sliver of tissue is fixed in formalin and embedded in paraffin, then sliced into micrometre-thin sections. These are stained to highlight particular molecules.

Then things get more precise. Mund's team uses high-resolution microscopes and AI image analysis to create detailed digital maps of the tissues, showing each cell's boundaries and flagging those that appear abnormal.

A laser dissection microscope then cuts out labelled cells one by one, tracking their position in the original tissue. Each cell is broken apart, its constituent proteins shattered and analysed by mass spectrometry, a method that weighs molecules with incredible precision. "We use the latest and greatest on the market," says Mund. Their mass spectrometers are so sensitive that they can detect differences equivalent to the weight of a jumbo jet versus a jumbo jet with a fly sitting on it.

The outcome is a powerful molecular map: a profile of every cell and the proteins it contains. Crucially, it allows researchers to compare healthy and abnormal cells and detect patterns of dysfunction that were previously invisible.

In a paper released in July, Mund and his colleagues looked at a kind of pancreatic cancer in which tumours form from distinctive lesions within the pancreas, but not all of these lesions go on to be tumours. "Why are these so different? What are the molecular differences?" asks Mund.

To find out, they analysed over 8000 proteins across cells from five people with this cancer and 10 cancer-free organ donors. Even cells that looked normal under the microscope showed early signs of tumour development in people with cancer: inflammation, metabolic rewiring and other stress markers.

He and his team argue their work could lead to biomarkers for earlier detection, a major step for one of the deadliest cancers.

And deep visual proteomics is just one part of this new set of technologies, each aimed at unravelling the spatial story of disease in place, cell by cell.

Another promising way to track what is happening inside a cell is by looking at its RNA.

RNA plays a key role in gene expression. Genes store instructions in DNA, but to act on them, cells first transcribe that information onto RNA. The resulting RNA then guides protein production, the main outcome of gene expression. By examining which RNA molecules are present in a cell, a profile known as its transcriptome, scientists can get a snapshot of the cell's condition, including what it is trying to do or cope with at any given time.

Spatial transcriptomics involves mapping the cells in a tissue and then studying their individual transcriptomes. "Spatial transcriptomics, I think, takes us to the next level," says Kahlenberg.

In July, researchers led by Ernst Lengyel at the University of Chicago used spatial

transcriptomics to develop a potential treatment for ovarian cancer. They focused on a group of cells called cancer-associated fibroblasts, which help tumours grow. These cells were already known to respond to an enzyme called NNMT. Using spatial transcriptomics, they discovered that this response caused fibroblasts to release chemicals that dampened the immune system, shielding the cancer. That insight led the team to create an NNMT inhibitor that, in mice, enabled the immune system to go to work and reduce the growth of tumours.

Transcriptomics and proteomics are complementary, says Sinicrope, because they give different kinds of information about the cell. "RNA gives us more in terms of the pathways and the signatures."

CRISTIAN STORTO/ALAMY

Toxic epidermal necrolysis can be a side-effect of common drugs, like antibiotics and anti-epilepsy medications

Cracking the killer

Meanwhile, halfway across the world at the Max Planck Institute of Biochemistry Nordmann was using spatial proteomics to crack the TEN mystery.

Nordmann arrived in Martinsried, Germany, from his position in Switzerland, armed with Mund's new approach of studying diseases and a drawer full of skin samples from people with TEN. Having followed Mund's team's work on ovarian cancer, he and his colleagues sought to understand the underlying mechanisms that cause skin to detach in TEN.

The deep visual proteomics revealed a striking pattern. In the immune cells of the TEN patients, a molecular system called the interferon pathway was massively overactive. "I have really never seen such a clear picture in my life," says Nordmann.

Normally, interferons are produced by cells in response to viral infection. They prompt other cells to activate their antiviral defences. But in Nordmann's TEN patients, there was no virus: the interferon response was a mistake and was causing the immune system to destroy the outer layer of their skin.

The team discovered that a signalling pathway called JAK/STAT was driving the cells to produce interferons.

Excitingly, there are already drugs that block this signalling pathway, as it is implicated in other inflammatory conditions such as rheumatoid arthritis and atopic dermatitis, so they could work for TEN too. "The cool thing is, there are already inhibitors out there," says Nordmann.

With the help of Chao Ji at Fujian Medical University in Fuzhou, China, who had been following the team's research, Nordmann launched the first human trial in 2023. They treated seven TEN patients, all of whom were still alive with no side effects 30 days later, the duration of the study. One man who had lost 35 per cent of his outer skin grew almost all of it back within 16 days; the treatment halted cell death in all patients and promoted a regrowth of skin.

Though it wasn't a controlled study, because the team didn't want to give some TEN patients a placebo, Nordmann is now trying to get a pharmaceutical company to set up a full clinical trial.

For the first time, TEN had been effectively treated. It was a huge leap forward from where doctors were just a few years ago, when they were forced to treat TEN patients essentially as severe burn victims: giving them fluids, anti-inflammatories and something for the pain.

"My personal opinion is, in two to three years' time, this will be the standard treatment for this disease," says Nordmann.

It will take a while before spatial multiomics technologies are used widely in research and in clinics. Running a few hundred samples through spatial multiomics can cost millions of dollars. But some hospitals are already placing big bets on this new approach.

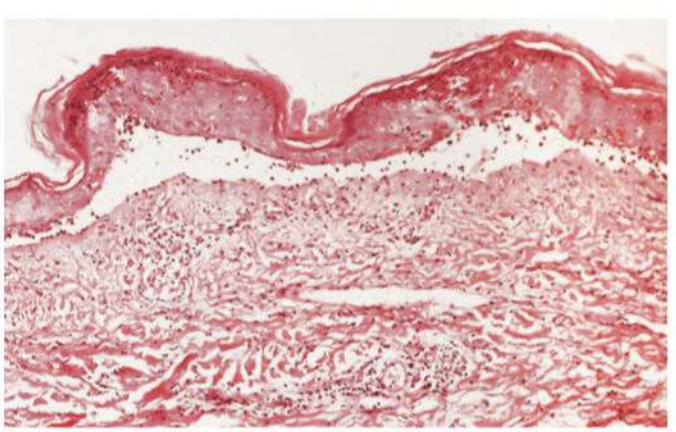
The Mayo Clinic has established a Spatial Multiomics Core to perform such analyses. The researchers there hope to better understand atherosclerotic plaques, which are a major element of heart disease, by figuring out what their many component cells are doing.

Similarly, diabetes can cause complications in the gut, so identifying the gut cells most prone to such damage would be a key step in preventing it.

And for his part, Sinicrope, who leads the Spatial Multiomics Core, is optimistic that spatial multiomics will help with cancer, especially solid tumours.

Meanwhile, Mund and his colleagues founded a company called OmicVision in 2023 off the back of their deep visual proteomics technique, with the aim of reducing how laborious and complex it is to carry out. Mund hopes to drive the cost down and make the technology more widely available. "Our mission is really to move the needle," he says.

Five years since he started working with spatial multiomics, Nordmann remains thrilled by its potential. "You get an entire new picture, an entire new understanding of the molecular information within a tissue," he says. "It gives us new ideas of how to diagnose them, understand them, treat them." ▮



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A micrograph showing the top layer of skin starting to detach in someone with toxic epidermal necrolysis

Michael Marshall is a science writer focused on life sciences, health and the environment

AGES 7–14

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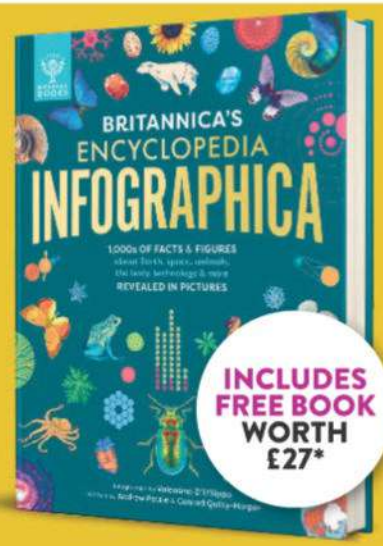

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The science of exercise

Festive fitness

A chaotic schedule over the holiday season often derails **Grace Wade**'s workout routine. But this year she has a plan...

Grace Wade is a health reporter for *New Scientist* based in the US

THE holidays are always the most stressful part of my year, no matter how much I try to plan ahead. Amid the chaos, my usual workout routine – and often exercise altogether – falls by the wayside. But I am determined for this year to be different.

Consistency is key when it comes to fitness, and part of staying consistent is being adaptable. So I am going to get creative. To start, I want to make sure I am being as efficient as possible with my time. Research shows that high-intensity interval training (HIIT) – exercising at near maximum effort in repeated bursts with short rests in between – is one of the most effective workouts. It was born out of a 1990s study that found a 4-minute workout, consisting of repeated cycles of 20 seconds of intense exercise followed by 10 seconds of rest, improved aerobic fitness more than hour-long moderate workouts, when done five days a week for six weeks.

On those days when I have even less time, there are still ways for me to maintain my fitness. A 2023 study of more than 22,000 adults who didn't exercise found that 3.5 minutes of vigorous activity a day was associated with a lower risk of cardiovascular disease in women. In a separate analysis of people who deliberately exercised, short bursts of vigorous activity were associated with a 20 per cent lower risk of heart attack and stroke for both women and men.

These bouts of intense activity, which I like to think of as "exercise snacks", could include chasing after the bus, lugging your groceries home or, in my case, sprinting through the airport with presents in tow. It could even be as simple as hustling up the stairs. A 2019 study found that vigorously climbing three flights of stairs three times a day, three days a week, could improve a measure of cardiovascular fitness by about 5 per cent after six weeks.

ROMY ARROYO FERNANDEZ/NURPHOTO VIA GETTY IMAGES

Another, less intense option is to keep my step count up. Most targets call for 10,000 steps a day, but a 2025 study showed that just 7000 was enough to lower the risk of heart disease, type 2 diabetes, dementia and early death. Going on long walks is a great way for me to stay active over the holidays while catching up with my family members.

I believe these three options – HIIT workouts, exercise snacks and leisurely walks – can easily fit into my chaotic schedule. But even if they can't, I am not too worried about my health. A month without exercise shouldn't put me back at square one. In fact, notable declines in muscle strength don't occur until about two or three months of inactivity. Aerobic fitness fades faster, usually after a month without exercise. So if you can only prioritise one type of activity, focus on getting your heart pumping. And remember: the most important thing is to get back into your workout routine once the holidays end. ▮

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The science of exercise appears monthly

Next week
Dear David

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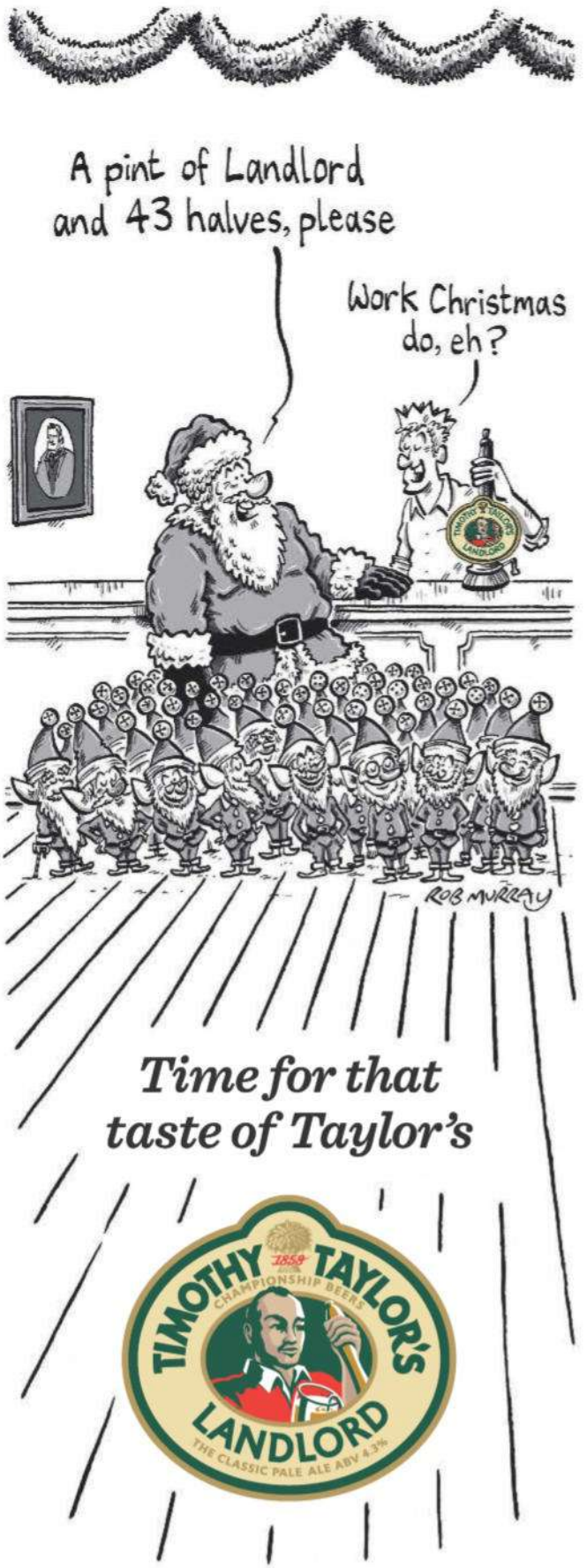
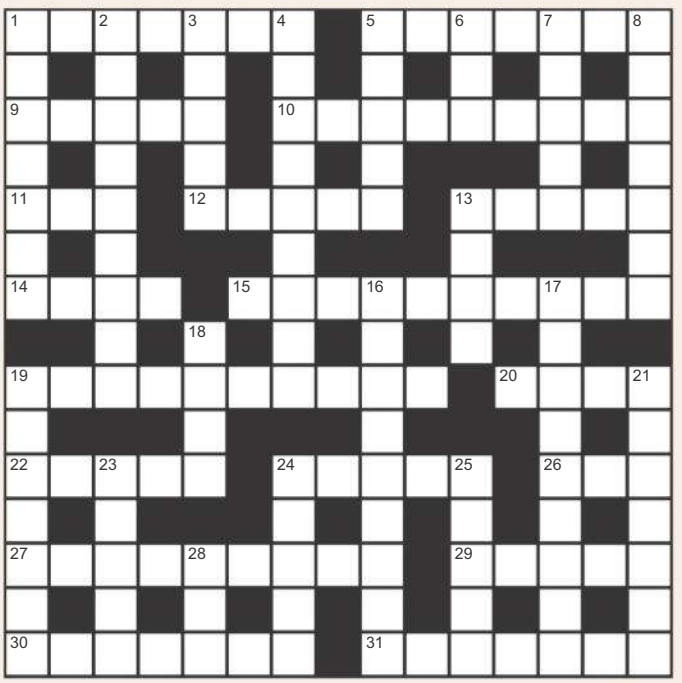


Quick crossword #197 *Set by Richard Smyth*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Unused resources (7)
5 Fuel mixture known as E10 (7)
9 Fast-flying migratory bird, *Apus apus* (5)
10 Quadrilateral with one pair of parallel sides (9)
11 Nintendo games console (3)
12 An octave plus a second, in music (5)
13 Propulsive mechanism (5)
14 Acronym warning against sloppy coding (4)
15 Obsolete data storage device (6,4)
19 Artillery soldier (10)
20 Flake of precipitate, in chemistry (4)
22 Figure out, crack (5)
24 Animal that forms part of a colonial organism (5)
26 Long-snouted fish (3)
27 Nettle rash (9)
29 Roger ___, medieval English polymath (5)
30 # (7)
31 Recurring at uniform intervals (7)

DOWN

1 Acronym suggesting that something may be taken at face-value (7)
2 Adhesive made from solvent and resin (6,3)
3 Multifunctional cell protein (5)
4 Intertwined (perhaps in a quantum sense) (9)
5 Data chart (5)
6 Witness, observe (3)
7 Lifting mechanism (5)
8 Jean-Baptiste ___, evolutionist (7)
13 ___ Clinic, US healthcare centre (4)
16 Extinct flying reptile (9)
17 Non-rational (9)
18 Ripple (4)
19 Bi (7)
21 Official concerned with causes of death (7)
23 Legume; sports car (5)
24 Weightlessness (4,1)
25 Remove flaws from (software) (5)
28 Hundredweight (abbreviation) (3)

Our games are now solvable online
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Quick quiz #330
set by Tom Leslie

1 A three-legged lion that recently made headlines for his hunting habits also broke his species' distance swimming record last year, alongside his brother. But what is his name?

2 What is the topic of Shinichi Mochizuki's controversial 500-page mathematics proof, which may soon be tested by a machine?

3 Orcas in the Gulf of California have been reported doing what to great white sharks?

4 A 40,000-year-old crayon from Crimea that researchers believe Neanderthals used is made from which material?

5 A new analysis of thousands of holes dug into a mountain in Peru found they may have been used for what purpose?

Answers on page 55

BrainTwister
set by Howard Williams

#101 Knight's progress

On an eight-by-eight chessboard, a knight can move two squares vertically and one square horizontally, or two squares horizontally and one square vertically. The knight starts on the black bottom-left square.

After three randomly chosen moves, what is the probability that the knight will end up on a black square?

The knight has a target square that it moves to in as few moves as possible. What is the largest number of moves it could possibly take?

Moving at random, on how many of the 64 squares could the knight be after four moves?

Answers next week

Wake-up call

My partner says he wakes up in the night as he needs to urinate. But could it be he needs to urinate because he has woken up?

Emily Henderson
University of Bristol, UK
You are both correct! At night, the brain and bladder debate whether to get you up to pass urine or to let you rest. Most of the time, the bladder calls the shots. As urine accumulates, stretch receptors send signals to the brain, and once the message is strong enough, you wake. If this happens more than once a night, it is called "nocturia".

Nocturia can be triggered by all sorts of things. Hormone changes can cause the kidneys to produce more urine at night. Fluid retained in the body during the day can shift when you lie down, thereby filling the bladder. Disorders of the urinary tract or prostate can also play a role.

Beyond that, medical conditions affecting sleep, the heart, the kidneys or the hormones – as well as certain medications – can all have an impact. But the urinary system isn't just plumbing. Behavioural cues matter too. You might have noticed how the

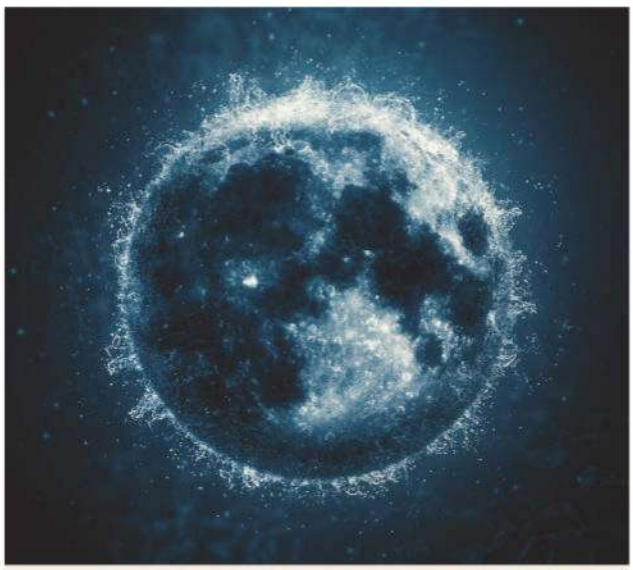
"At night, the brain and the bladder debate whether to get you up or let you rest. Most of the time, the bladder calls the shots"

sound of running water makes you want to go? These learned associations are examples of the brain triggering bladder action.

Stefan Badham
Portsmouth, Hampshire, UK
Being an insomniac, I wake up, on average, around 20 to 30 times every night. If waking up triggered a need to urinate, then I would have to do it every time I woke up, which I don't. However, a need to urinate always wakes me up. And thank goodness it does.

Tony Green
Ipswich, Suffolk, UK
I frequently find myself dreaming that I am urinating, but no matter how much I do so in real life, the dreaming-me keeps on peeing. Fortunately, my unconscious mind has learned that it needs to wake me up and I am always desperate for a trip to the toilet when it does. A single datum, but it leaves me in no doubt which way round cause and effect sit.

James Hardy
Belfast, UK
As a retired GP, I appreciate how urinary problems can interfere with sleep. But poor daytime choices, like excess caffeine and fluids in the latter half of the day, are surely a more common cause. In our hyperactive society, is a lot of sleep disturbance related to compulsive coffee consumption to stay awake? Adjustment of fluid intake, and wise choices on afternoon beverages, can bring welcome rest at night.



SHUTTERSTOCK/NASA IMAGES

If all the water on our planet were formed into a ball, how large would it be?

This week's new questions

Water world **If all the water on Earth's surface and in the air were put into a ball, how large would the sphere be? Could it exist in space by itself?** ***Jim Wegryn****, Lansing, Michigan, US*

On your marks **If a fit human being and a cheetah were to run a race, how long would it have to be for the human to win?** **Goronwy Humphreys***, Wallasey, Merseyside, UK*

Spinning around

If a very large disc on a frictionless, horizontal spindle were gradually rotated faster and faster, what would happen as the rim approached the speed of light? (continued)

Ron Dippold
San Diego, California, US
Sadly, a disc could never approach the speed of light. If you had a high-strength steel disc that was 1-metre thick and 1 kilometre in diameter, it would come apart from centrifugal force at just 11 revolutions per minute or so. Even if the disc were made from the strongest possible diamond, you could only get the rim up to 8.6 kilometres per second (164 revolutions per minute) before it shattered. The material with the highest theoretical tensile strength is carbyne, a form of carbon estimated to be up to three times as strong as the strongest possible diamond. That would reach 26 km/s before shattering.

What if you took a neutron star and made a disc out of it? Without being a sphere, it would fall apart, but assuming you could somehow keep it as dense as a neutron star, even at the most extreme density estimates of 300 quadrillion times stronger than carbyne, you could only get the rim up to about 900 km/s (3/1000th the speed of light) before it broke, because the strength scales with the square root.

Well, let's set all that aside and assume the disc is made of infinitely strong handwavium, which happens to be as dense as diamond. To pump enough energy in to get the rim up to 99 per cent the speed of light, you would need about 200 septillion joules. That sounds huge, but it is "only" about 35 years of all the solar power reaching Earth.

Going back to our 1-metre-thick disc, if you or I were at the rim, we would be instantly squished to single atom thickness or flung off into the far reaches of space by centrifugal force. If we handwave some more and say we could survive at the rim, you would see strong time dilation: 1 minute for us there would be 7 minutes on Earth. But would that really be worth stealing all Earth's energy for 35 years?

Mike Follows
Sutton Coldfield, West Midlands, UK
No very large disc could ever spin anywhere near the speed

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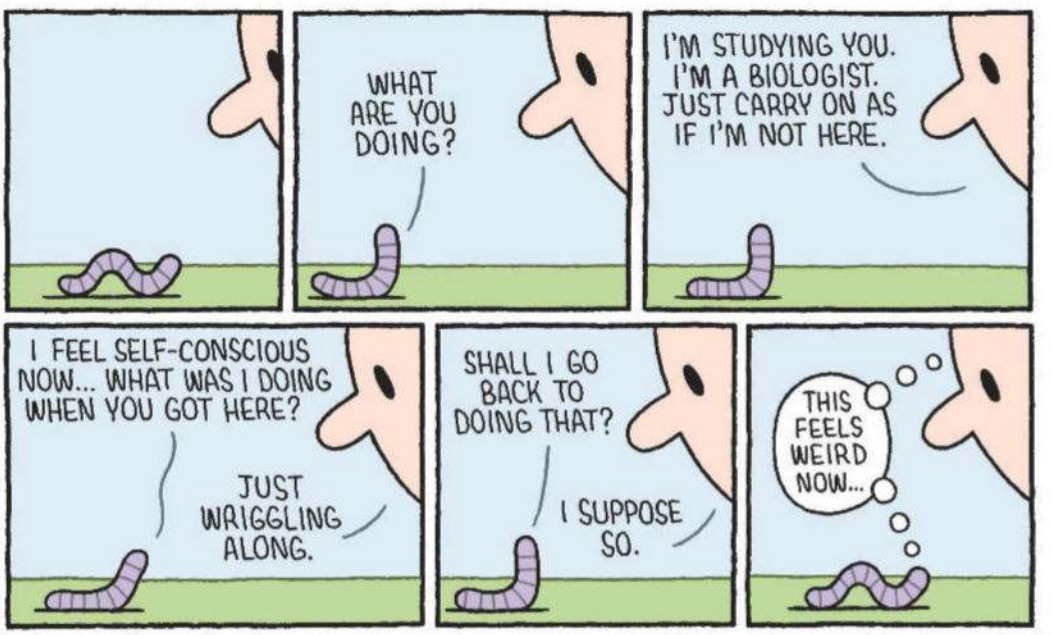


of light before falling apart, as the atomic bonds simply aren't strong enough, so pieces would fly off the edge once the stress became too great.

Smaller objects can spin much faster before breaking. Take a silica nanoparticle, just 150 nanometres across: scientists have spun one at over 300 million revolutions per minute. Even at that incredible angular speed, its circumference was moving at only a few metres per second – a consequence of its tiny size.

Interestingly, the maximum rim speed depends on the material, not the size of the disc. Steel can only manage around 500 metres per second, whereas graphene could reach nearly 8000 metres per second, thanks to its exceptional strength and low density.

Switching from a disc to a cylinder doesn't help much – in fact, it would result in the object falling apart at an even lower rotational speed. A rotating space habitat based on an O'Neill cylinder would need to be spun

"No disc could ever spin anywhere near the speed of light before falling apart – the atomic bonds simply aren't strong enough"

fast enough so that people walking around on its inner surface would experience the same force of gravity that we feel on Earth's surface. However, comfort dictates that the spin rate should be less than 1 revolution per minute, which requires a radius of at least 1 kilometre, although the maximum size is ultimately limited by the material's strength.

I know you

Which animals can recognise individual people? Are there fish, reptiles or insects that can do this? (continued)

Maggie Richards
Richmond, California, US
I am pretty sure my leopard gecko knows who I am. When she was a couple of years old, I went away for several days, leaving her in the care of my son. Upon my return, I went in to say hello to her. She looked out, did a double-take, then came all the way out of her hide, apparently to see if it was really me. She may recognise me using scent and aural cues as well, but this was the first – and only – indication that she can identify me by sight alone.

Geoff Sawers
Reading, Berkshire, UK
In her answer to this question, Sara Paisa writes about her local magpies in Bucharest recognising her face. Where I work, a colleague of mine has a small patch of flat roof just beside his desk and he regularly throws unsalted mixed nuts onto it for the local carrion crows to enjoy.

Now, he and I are both slim, white men in our 50s and might look similar to a crow, but if I approach his window, the birds scatter at once. I am clearly not the human that they have so carefully trained to bring them treats. ▮

Answers

Quick quiz #330 *Answer*

1 Jacob
2 The ABC conjecture
3 Flipping them over and eating their livers
4 Ochre
5 Accounting

Cryptic crossword #175 *Answers*

ACROSS 1 Barometer, **6** App, **8** Ski trip, **9** Mason, **10** Knee, **11** Acronym, **13** Radish, **15** Kepler, **18** Sawfish, **20** Comb, **22** Baize, **23** Babbage, **24** Ear, **25** Desiccant

DOWN 1 Bask, **2** Reigned, **3** Merge, **4** Top hat, **5** Remorse, **6** Arson, **7** Penumbra, **12** Erasable, **14** Stipend, **16** Lambada, **17** Thebes, **19** Whirr, **20** Cubic, **21** Jest

#100 Tricky angles *Solution*

The answers to all three parts of our 100th BrainTwister are 100.

Too tight to mention

Feedback is one of many holidaymakers to have run afoul of French swimwear rules. For those unaware, men using a public swimming pool in France (and some parts of Italy) are compelled by law to wear tight swimming briefs. Loose shorts are forbidden. This is why you will never find Feedback in a French swimming pool.

Feedback was going to refer to these tight-fitting garments as "budgie smugglers", a piece of Australian slang that has made its way to the UK. Then we learned that there is actually an Australian swimwear brand called Budgy Smuggler, whose bestsellers include swimming briefs decorated with brown and pink hibiscus, and we decided not to go there.

Anyway, let us meander in the general direction of the point. Subeditor Thomas Leslie came across a paper on medRxiv, describing "a cross-over study among male academics" on the relative merits of swimming briefs and shorts. We cannot begin to imagine what search terms Thomas used to discover this paper.

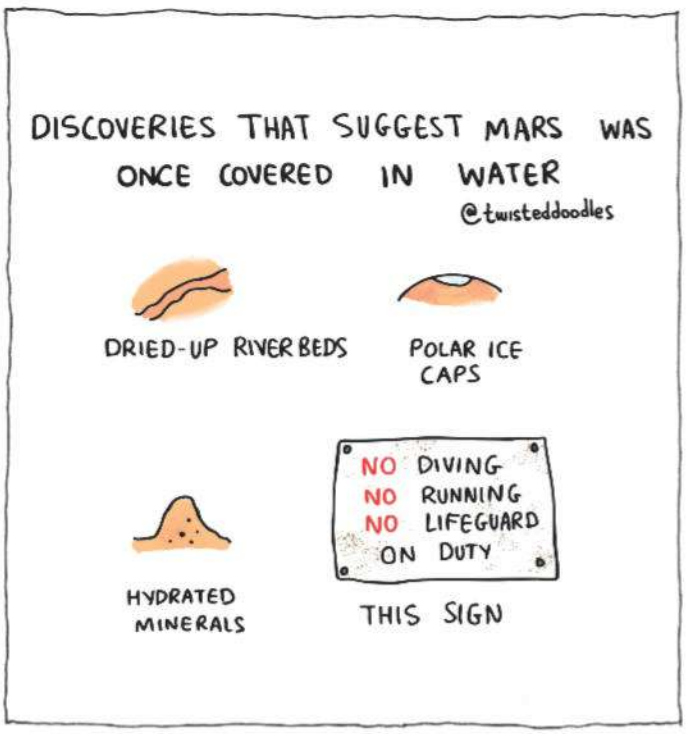
Let's dive in. The authors explain that France insists on briefs for hygiene reasons, because "looser garments may introduce external contaminants into the pool and its environment". However, "these claims have never been substantiated". The team therefore recruited 21 male academics, luring them with the promise of free briefs. They were asked to wear either shorts or briefs under their clothes for 2 hours, then remove them and immerse them in water. The researchers tested the water for bacteria and found that water from shorts had more bacterial growth than that from briefs.

As a follow-up, five of the participants tried swimming in "local waterbodies". However, this proved "rather eventful". One volunteer had his clothes stolen, "leaving the participant in a slightly embarrassing outfit in public". A second experiment was ruined when a participant left his briefs to dry on a rock while swimming in his shorts, whereupon "a dog (*Canis lupus familiaris*) briefly urinated on [them]".

Feedback must confess to being mildly confused by the experiment. If shorts carry a heavier bacterial load, but you have to squeeze them out in water to release the microbes, is that really a problem? The authors themselves say they aren't sure what's going on. "It is possible that contaminant release from the gastrointestinal tract is lower in [briefs] due to their elasticity exerting external pressure on the gluteal muscles, thereby reducing contact between the rectum and the fabric." That does seem possible.

Alternatively, maybe fluid dynamics plays a bigger role in bacterial release from shorts. "Surprisingly, the impact of pool hydrodynamic drag on fecal bacterial shedding is grossly unexplored and to the best of our knowledge, no studies have ever examined fluid dynamics inside different types of swimwear," the authors write. Someone, please: write that grant proposal.

Twisteddoodles *for New Scientist*



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A bold bald build

It has finally happened: Lego has signed a deal with the owners of *Star Trek*, and their first release is a big model of the Enterprise-D from *The Next Generation*. Full marks to the designers for starting with something so difficult: the Enterprise-D has a sleek design, with curves everywhere and barely a straight line to be found, so building it out of (mostly) rectangular blocks is a big swing.

Alas, in solving this design challenge, the Lego people missed a fine detail. Hidden inside the model is a gold plaque that reads "To boldy go where no one has gone before."

Funky rodents

Suppose you're worried that your lab mice are bored, so you decide to play them some music to keep them entertained. What should you put on?

That's the question asked by Johann Maass and his colleagues in *Frontiers in Behavioral Neuroscience*, in a paper called "Taylor Swift versus Mozart: music preferences of C57BL/6J mice".

They point out that, when researchers play music to mice, they generally choose the same piece: *Sonata for Two Pianos in D major, K.448* by Wolfgang Amadeus Mozart. This is the piece that supposedly boosts your child's intelligence if they listen to it – you know, the famous "Mozart effect" that was resoundingly debunked years ago. (The key evidence against it came in a 2010 study titled, gloriously, "Mozart effect–Schmozart effect: A meta-analysis".)

It's kind of weird that biologists are so keen to play this non-brain-enhancing Mozart piece to mice. As the authors point out, "mice have a hearing range of about 2 kHz to 100 kHz" and much of the sonata is below 1 kHz – so the mice probably can't even hear most of it.

Consequently, the researchers created the Mouse Disco Testing Arena: four soundproofed rooms, connected by tunnels. Each had different music playing. One had the Mozart. Another had electronic dance music, "represented by the first 60 min of *The Very Best of Euphoric Dance: Breakdown 2001 – CD1*". A third had a selection of what the team calls "classic rock" and what Feedback would call "naff rock", including songs by Nazareth, FireHouse and (horror of horrors) Whitesnake. The fourth had a Taylor Swift playlist.

The mice showed no preferences – except that they spent almost no time in the Mozart room. Take that, Amadeus.

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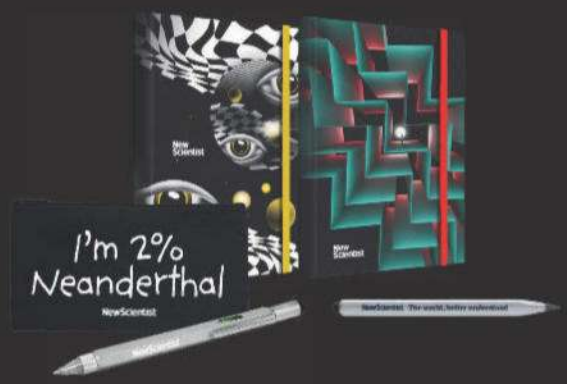

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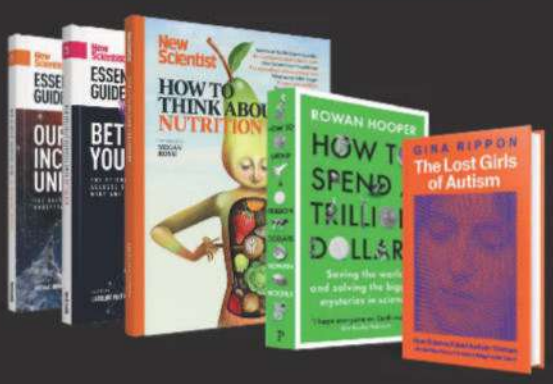

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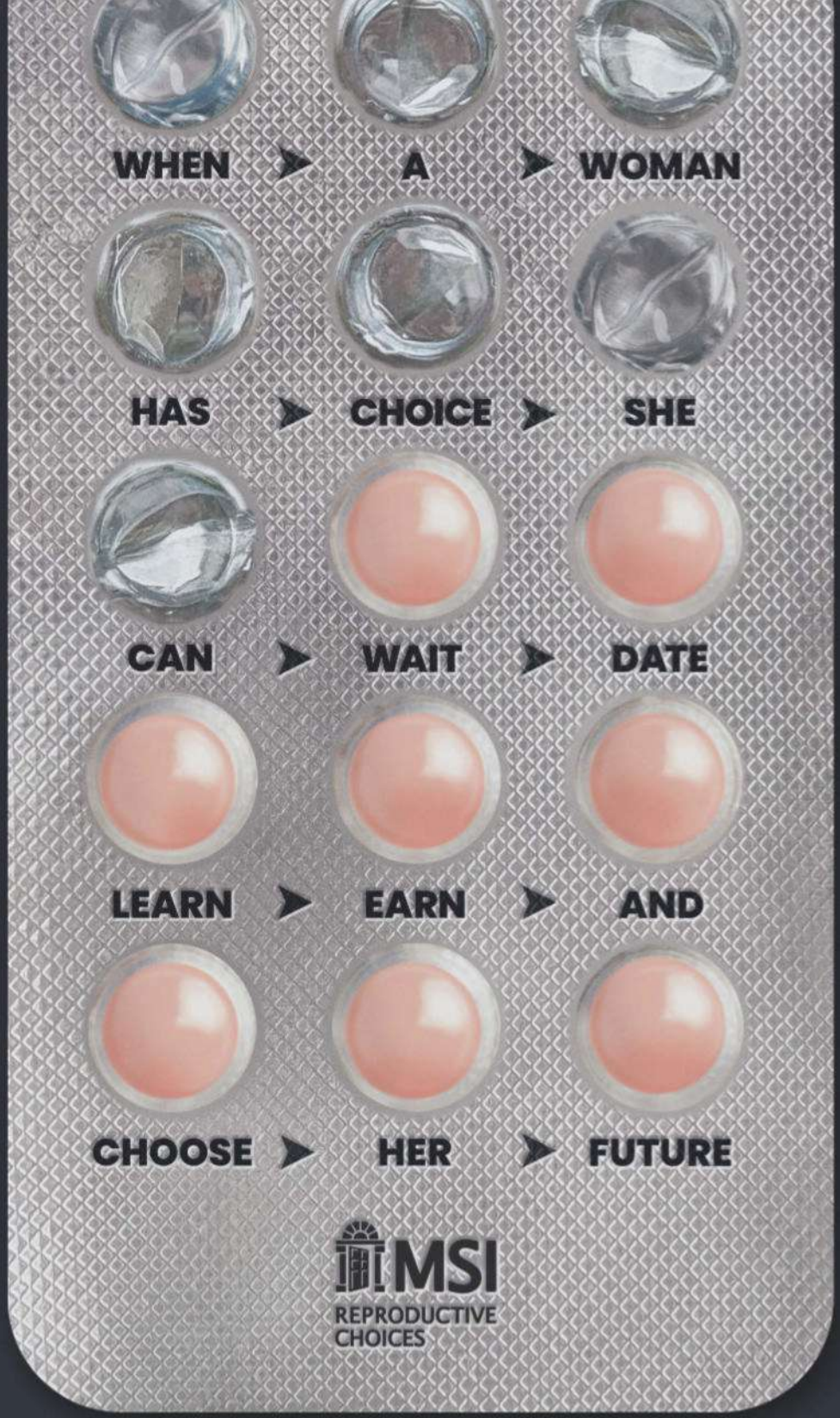

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